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X. *On the African Species of the Genus* Coffea, *Linn.* *By* W. P. Hiern, *M.A., F.L.S.*

(Plate XXIV.)

Read April 20th, 1876.

As at present understood, the Linnean genus *Coffea* belongs to the Old World; and the numerous American species that have been previously referred to it, now find places in other genera. All the species most valuable for economic or commercial purposes are confined to Africa or are of African origin. Among the Indian species, at least one, *C. bengalensis*, Roxb., a native of Silhet, was in former times cultivated in Bengal for the growth of coffee; but being far inferior and not productive, it has been discarded on the introduction of the African plants.

Some of the Indian species originally described as members of this genus, belong to the following different genera:—*Psychotria*, Linn.; *Prismatomeris*, Thw. (*C. tetrandra*, Roxb.); and *Pavetta*, Linn.

The American species belong to *Appunia*, Hook. f. (*C. tenuiflora*, Benth.), *Coussarea*, Aubl., *Faramea*, Aubl., *Psychotria*, Linn., *Palicourea*, Aubl., and *Rudgea*, Salisb.

In Africa, besides the true species of *Coffea*, other berries are employed as coffee; but they are not of commercial importance: an example of this occurs in *Feretia apodanthera*, A. Rich. *Randia genipæflora*, DC., is called wild coffee by the people at Sierra Leone and in the island of Fernando Po, according to Barter's notes in the Kew Museum and Herbarium.

Of the species included in the present paper, in all fifteen, seven have been already published with descriptions, and the remaining eight are new or have not been previously described. One species, *C. arabica*, the original species of the genus, is believed to be indigenous in Abyssinia, also on the shores of the Victoria Nyanza and in the district of Golungo Alto in Angola, doubtfully also along the Mozambique coast, while the white-berried variety comes from Sierra Leone. Another species, *C. liberica*, belongs to Liberia, to Golungo Alto, and to Sierra Leone, though perhaps only cultivated in the latter place; two other species, *C. stenophylla* and *C. Afzelii*, are peculiar to Sierra Leone; one, *C. microcarpa*, to Senegambia; another, *C. rupestris*, to Abbeokuta; another, *C. brevipes*, to the Cameroons Mountains; another, *C. subcordata*, to Old Calabar; one, *C. jasminoides*, is common to Old Calabar, to the Niger region, and to Golungo Alto; another, *C. melanocarpa*, is peculiar to Golungo Alto; another, *C. hypoglauca*, to the district Pungo Andongo of Angola; two, *C. Zanguebariæ* and *C. racemosa*, to the Mozambique district; and, lastly, two, *C. mauritiana* and *C. macrocarpa*, to the Mascarene Islands of Bourbon and Mauritius. In other words, Upper Guinea contains 9 species, Nile Land 1, Lower Guinea 5, and Mozambique district with the Mascarene Islands 4 or 5.

The following key determines the classification of the species:—

Coffeæ *speciebus Africanis clavis adaptata.*

Glabræ, pleræque sempervirentes. Flores axillares.
- Calycis limbus brevissimus, annularis vel denticulatus.
  - Antheræ omnino exsertæ.
    - Bracteolæ obtusæ vel apiculatæ, calyce breviores. Flores glomerati, rarius solitarii.
      - Corolla pentamera . . . . . 1. ARABICA.
      - Corolla hexamera vel heptamera vel octamera.
        - Baccæ teretes. Folia subcoriacea.
          - Flores glomerati. Folia breviter acuminata, 6–12-pollicaria . . . . 2. LIBERICA.
          - Flores terni vel gemini vel solitarii. Folia caudato-acuminata, $2\frac{1}{2}$–5-pollicaria . . . . . 3. STENOPHYLLA.
        - Baccæ nervis longitudinalibus angulatæ. Folia chartacea . . . . . 4. ZANGUEBARIÆ.
    - Bracteolæ per paria lanceolatæ acutæ et deltoideo-apiculatæ, calyce longiores. Flores solitarii . . . . . 5. BREVIPES.
  - Antheræ semiinclusæ.
    - Baccæ utrinque rotundatæ. Folia chartacea . . . . . 6. MELANOCARPA.
    - Baccæ utrinque acutæ. Folia coriacea.
      - Folia 2–3-pollicaria, tenuiter coriacea. Corolla $\frac{1}{4}$-pollicaris . . . . 7. MAURITIANA.
      - Folia 5–6-pollicaria, valde coriacea. Corolla $\frac{1}{2}$-pollicaris . . . . . 8. MACROCARPA.
- Calycis limbus latus, lobis 5 rotundatis.
  - Stipulæ lanceolatæ subulatæ. Bracteolæ parvæ, non foliaceæ.
    - Baccæ subglobosæ, solitariæ vel subgeminæ. Folia 3–9 poll. longa, $1\frac{1}{4}$–$3\frac{1}{2}$ poll. lata . . . . . 9. HYPOGLAUCA.
    - Baccæ ellipsoideæ. Flores secus ramulos ad axillas fasciculati. Folia $2\frac{1}{2}$ poll. longa, $\frac{2}{3}$–$\frac{3}{4}$ poll. lata . . . . . 10. MICROCARPA.
  - Stipulæ e basi lata ovata apiculatæ. Bracteolæ foliaceæ . . . . . 11. AFZELII.

Non omnino glabræ. Folia decidua. Flores terminales axillaresque vel laterales vel ramulos breves laterales terminantes.
- Folia ovalia, puberula vel glabra.
  - Antheræ omnino exsertæ. Flores cum foliis coævi . . . . . 12. SUBCORDATA.
  - Antheræ fere inclusæ. Flores præcoces.
    - Bracteolæ herbaceæ. Calycis limbus truncatus vel denticulatus. Corolla 5-loba . . . . . 13. RUPESTRIS.
    - Bracteolæ glumaceæ. Calycis limbus rotundate lobatus. Corolla sæpius 7–6-loba . . . . . 14. JASMINOIDES.
- Folia ovato-lanceolata, tuberculis plurimis consita, scabra . . . . . 15. RACEMOSA.

1. COFFEA ARABICA, Linn. Sp. Pl. p. 172 (1753).

C. laurifolia, Salisb. Prodr. Stirp. Hort. Chapel Allert. p. 62. n. 1 (1796), non Kunth.

Hab. Indigenous in Abyssinia, also on the slopes above the Victoria Nyanza (*Grant*), and in Angola (*Welwitsch*), and probably in some of the intervening countries; cultivated and often occurring spontaneously in Arabia and nearly all tropical and subtropical countries, including Madagascar and Natal; said to be wild along the Mozambique coast [see Klotzsch in Peters, Mossamb. p. 291 (1862)]. It, with its numerous cultivated varieties, is the source of most of the coffee of commerce.

Dr. Welwitsch found this species quite indigenous in primitive woods throughout nearly the whole district of Golungo Alto, as well as frequently cultivated; he describes it as a small tree, 10–15 feet high, with the trunk 9–12 inches in diameter at the base, and with horizontal or even nodding branches, which in old age become unilateral; it belongs to the 'Regio montoso-sylvatica' of Welwitsch, which ranges from 8° to 10° S. lat. and from 1000 to 2400 feet of altitude.

The commercial varieties of common coffee depend mainly upon their shape, size, and colour. The shape of the berries and of the seeds is said to depend on the particular portion of the plant on which they grow, those near the extremities being often obliquely rounded by the abortion of one of the seeds in the fruit; the size and succulence depend on the nature of the locality—those berries grown in a dry, hot, and rocky climate being smaller, less fleshy, and of superior flavour; and the colour depends on the degree of maturity attained by the fruit at the time of gathering. Some or all of these differences may also partly depend on the variety of the plant employed; but it is not known for certain whether the Mocha coffee is a distinct variety, or, as seems more probable, only due to a particular treatment and cultivation.

The following variety I have described, since it may prove to be a distinct species, characterized by white berries &c.; the flowers are unknown.

Var. *leucocarpa*, fruticosa glabra, foliis ellipticis vel ovali-oblongis breviter obtuse acuminatis basi cuneatis tenuiter coriaceis, venis lateralibus inconspicuis sub-6–7-jugis eglandulosis, stipulis e basi late ovata connata apiculatis petiolum brevem subæquantibus, floribus axillaribus subglomeratis, bracteolis ovatis quam pedicelli breves fructiferi brevioribus, baccis albis pisiformibus solitariis vel geminis, calycis limbo fructiferi obsoleto.

Hab. ad Sierra Leone, legit mense Junio anni 1841 *Th. Vogel!* no. 174.

Folia 3–6 poll. longa, 1–2 poll. lata. An species distincta?

2. Coffea liberica, sp. nova; Hort. Bull. Pl. XXIV.

C. fruticosa vel arborea glabra lucida sempervirens, ramis horizontaliter patentibus, foliis elliptico-obovatis oblongisve breviter acuminatis basi cuneatis vel obtuse angustatis subundatis tenuiter coriaceis $\frac{1}{2}$–1-pedalibus, nervis lateralibus utrinsecus 8–10 in alis puncto secretorio instructis, stipulis late ovatis apiculatis basi connatis quam petioli subbrevioribus, floribus axillaribus glomeratis subsessilibus pollicaribus, bracteolis connatis calyculatis depresso-deltoideis vel obtusis plerisque subtruncatis calyce brevioribus, calycis limbo annulari brevissimo, corollæ lobis 7–6 ovalibus obtusis tubum subæquantibus, antheris 7–6 omnino exsertis semipollicaribus, filamentis $\frac{1}{4}$-pollicaribus, stylo exserto bifido, baccis ellipsoideis $\frac{2}{3}$-pollicaribus vel ultra, seminibus semipollicaribus vel ultra.

C. arabica, Benth. in Hook. Niger Fl. p. 413 (1849), part., non Linn.

Hab. ad Sierra Leone, legerunt *Afzelius!* et *Daniell!* (cult.); in Monrovia, testibus *Th. Vogel* et *Daniell*; etiam in Angola (Golungo Alto et Cazengo) legit *Welwitsch!*

The source of the Liberian coffee, and probably also of the Cape-Coast coffee; it is said to be far superior to *C. arabica*, Linn., having larger berries, of a finer flavour, and being at the same time more robust and productive.

The name *Coffea liberica* was given by Mr. W. Bull, F.L.S., of Chelsea, in order to distinguish from the common coffee of commerce young plants which he obtained from seeds of Liberian coffee that had been sent from the west coast of Africa. He has since distributed the plant extensively under this name; but he had no idea whether it would prove to be a good species from a botanical point of view, nor did he intend the name to have any such sense or indication. However, as it turns out that the plant really constitutes a new species and requires a botanical name, I have thought it more convenient to adopt Mr. Bull's horticultural name, which has already received a wide distribution amongst plant-growers, rather than to take a manuscript name which Afzelius long ago gave to the same species in his herbarium, but which has never been published, and is entirely unknown to the public. Mr. Bull's name first appeared in his 'Retail List of new beautiful and rare Plants,' No. 97, page 4 (1874), and has been repeated in all the subsequent editions; he has given no botanical description.

The plant appears to have been first grown in this country in the year 1872 at Kew Gardens, from seeds contributed from Cape Coast, but only in very small quantity; in the following year living plants were imported from the west coast of Africa by Mr. Bull, who also in the same year obtained plants from seed; and at the same time numerous seedlings were raised at Kew. It is now produced on a large scale in this country for distribution to the various coffee-growing parts of the world.

3. Coffea stenophylla, G. Don, Gen. Syst. iii. p. 581, n. 4 (1834).

C. arabica, Benth. in Hook. Niger Fl. p. 413 (1849), part., non Linn.

Hab. Sierra Leone, *Afzelius !* and others.

In the Appendix to the Report of the Sierra-Leone Company, published in the year 1794, Afzelius states, on page 173, that "Coffee-trees are found of two distinct species, both nondescript; but whether of any use is not yet ascertained." This remark applies to this and the previous species. He subsequently discovered the economic value of at least this species.

According to G. Don, the seeds of this species are roasted and used as the common coffee, and are even considered superior to it. Afzelius, as has been explained, had recognized this as a distinct species; and among his manuscripts there remains a long description of it under an unpublished name of his own. It is the Highland coffee of Sierra Leone, according to Dr. Daniell.

4. Coffea Zanguebariæ, Lour. Fl. Cochinch. p. 145, n. 3 (1790).

Amazona africana, Spreng. Syst. Veg. ii. p. 126 (1825).

Hab. Zanzibar coast, *Loureiro*; Mozambique, *Forbes!*, *Loureiro* (cult.).

The seeds are said to be used in the same manner as those of *C. arabica,* Linn.

5. Coffea brevipes, Hiern, sp. nova.

C. fruticosa glabra nitida, ramulis gracilibus, foliis elliptico-obovatis acuminatis basi valde cuneatis firmiter chartaceis, venis lateralibus utrinsecus 6–8 gracilibus, stipulis e basi ovata valde vel rigide apiculatis petiolum brevem excedentibus, floribus axil-

laribus solitariis subsessilibus cum foliis coævis, bracteolis per paria lanceolato-acutis et deltoideo-apiculatis calycis limbum obsoletum excedentibus, corollæ lobis 5–6 ovalibus vel oblongis, antheris 5–6 omnino exsertis filamento bis longioribus, stylo exserto bifido, baccis lævibus ellipsoideis semipollicaribus solitariis.

Hab. in montibus Cameroons ad 2000–3000 ped. alt., legit mense Decembri anni 1862 *G. Mann !*, no. 2158.

Frutex 4–6-pedalis. Folia 4–8½ poll. longa, 1½–2¾ poll. lata. Flores dum expansi ⅕–¼ poll. longi.

6. Coffea melanocarpa, Welw. MS. in Herb.

C. fruticosa vel arborea glabra, ramulis erecto-patentibus, foliis ellipticis acuminatis basi cuneatis breviter petiolatis stipulos parvos obtusos excedentibus chartaceis, venis lateralibus utrinsecus 3–5 gracilibus, floribus pentameris sesquipollicaribus subsessilibus axillaribus subterminalibusque solitariis subgeminisve cum foliis coævis, calyce basi bracteolis omnino connatis calyculatis cincto, limbo annulari minimo, corollæ lobis ovalibus ½–¾-pollicaribus patentibus vel subreflexis, antheris majore parte inclusis subsessilibus stylo incluso, baccis demum aterrimis ellipsoideis vel subdidymis ⅓–½-pollicaribus.

Hab. in sylvis clarioribus circiter Sobati Bango et Bumba ad fluv. Delambra, in territorio Angolensi Golungo Alto non infrequens; mensibus Novembri et Decembri anni 1855 legit *Welwitsch !*

Frutex 4–6-pedalis, hinc inde arbuscula ejusdem altitudinis. Folia 1½–6 poll. longa, ½–2¼ poll. lata. Gemmæ florum exsudatione tenui vitrea fragili tectæ.

7. Coffea mauritiana, Lam. Encycl. Méth. i. p. 550, n. 2 (1783); Illustr. ii. p. 238. n. 3109, t. 160. f. 2 (1800).

C. arabica β, Willd. Spec. Pl. i. p. 974. n. 1, var. (1797), non Linn.

C sylvestris, Willd. in Roem. et Schult. Syst. Veg. v. p. 201. n. 28 (1819), fide DC. Prodr. iv. 499 (1830).

Hab. Bourbon, *Richard !*; Mauritius, *J. Grey !* In high mountainous forests.

Called *Café-marron* in Bourbon. It is mixed with other kinds of coffee; taken alone, it is said to have intoxicating properties.

8. Coffea macrocarpa, A. Rich. in Mém. Soc. Hist. Nat. Par. v. p. 168 (1834).

Hab. Mauritius, *Bouton !* In dense mountainous forests.

9. Coffea hypoglauca, Welw. MS. in Herb.

Arborea glabra, ramis patentibus, ramulis patulis, foliis ellipticis acuminatis basi plus minusve cuneatis tenuiter coriaceis nitentibus subtus glaucescentibus vel albescentibus, venis lateralibus utrinsecus 5–6 gracilibus, stipulis e basi lata lanceolato-subulatis acutissimis caducis petiolum excedentibus, baccis solitariis vel subgeminis axillaribus subsessilibus vel breviter pedicellatis subglobosis basi bracteolis ciliolatis imbricatis parvis rotundatis suffultis (immaturis viridibus pisi mole) apice calycis lobis 5 persistentibus imbricatis bracteolis conformibus coronatis.

Hab. in sylvaticis prope Catete in territorio Angolensi Pungo Andongo, cum fructibus mensibus Decembri anni 1856 usque ad Maium anni 1857 legit *Welwitsch!*

Arbuscula 8–15-pedalis et altior vel arbor parva 15–20-pedalis, ut videtur sempervirens, coma laxa, trunco recto gracili. Folia 3–9 poll. longa, $1\frac{1}{4}$–$3\frac{1}{2}$ poll. lata, petiolo $\frac{1}{5}$–$\frac{3}{5}$-pollicari; stipulis $\frac{1}{4}$–1-pollicaribus.

10. Coffea? microcarpa, DC. Prodr. iv. p. 499, n. 4 (1830), non Ruiz et Pavon.

C. Perrottetii (?), Steud. ex Buek, Index DC., pars 1, præf. p. ix (1842).

Hab. Senegambia, *Leprieur & Perrottet.*

I have seen no specimen of this species.

11. Coffea Afzelii, Hiern, sp. nova.

C. glabra, ramulis patulis rubescentibus, foliis ellipticis vel ovato-ovalibus obtuse acuminatis basi cuneatis chartaceis, venis lateralibus utrinsecus 4–5 gracillimis, stipulis e basi ovata apiculatis petiolum brevem subæquantibus, floribus pentameris geminis axillaribus pedunculatis basi bracteolatis, pedunculis prope basim bracteis 4 parvis oppositis præditis, bracteolis foliaceis, calycis limbo 5-dentato, corollæ lobis 5 ovalibus obtusis, antheris 5 sessilibus faucibus nudis infra os insertis, stylo glabro.

Hab. ad Sierra Leone, legit *Afzelius!*

Folia $1\frac{1}{2}$–3 poll. longa, $\frac{5}{8}$–$1\frac{1}{4}$ poll. lata.

I have seen only a single specimen of this species, in Afzelius's herbarium, in very young flower.

12. Coffea subcordata, Hiern, sp. nova.

C. fruticosa, ramulis teretibus hispidulis patentibus gracilibus apice hispido-pubescentibus, foliis ovalibus obtuse acuminatis mucronulatis basi subcordatis firmiter chartaceis supra costa excepta glabrescentibus infra secus costam et nervos laterales 4–5-jugos hispidulis, stipulis e basi deltoidea caudatis setoso-apiculatis deciduis petiolum brevem æquantibus, floribus vel terminalibus glomeratis et axillaribus solitariis vel geminis et ramulos abbreviatos laterales terminantibus (4-) 5–6 (–7)-meris fragrantibus cum foliis coævis, bracteolis calycem excedentibus herbaceis quibusdam subfoliaceis, calycis limbo glabro 5-fido lobis rotundatis, corollæ niveæ tubo gracili lobis ovalibus obtusis, antheris omnino exsertis, stylo exserto glabro bifido, baccis rubris.

Hab. ad oppidum Old Calabar frequens; legit mense Martio anni 1863, cum floribus, *Rev. W. C. Thomson!* no. 35.

Folia usque ad $3\frac{1}{4}$ poll. longa et $1\frac{1}{3}$ poll. lata pervenientia. Flores $\frac{3}{4}$–$\frac{7}{8}$-pollicares, suaveolentes.

13. Coffea rupestris, Hiern, sp. nova.

C. fruticosa subglabra, ramis subteretibus cinereis patulis ramulis puberulis, foliis deciduis ovalibus utrinque angustatis glabris chartaceis, stipulis ovatis acutis vel apicu-

latis, floribus præcocibus pentameris candidis sessilibus ad ramulorum apices glomeratis fragrantibus, bracteolis herbaceis late ovatis apiculatis calycis limbum subtruncatum vel denticulatum brevem excedentibus, corollæ lobis ovalibus obtusis tubum æquantibus, antheris sessilibus majore parte inclusis, stylo bifido.

Hab. in rupibus ad oppidum Abbeokuta, legit *Barter !* no. 3343.

Frutex parvus; folia (juvenilia) pollicaria; flores pollicares.

14. Coffea jasminoides, Welw. MS. in Herb.

C. fruticosa plus minusve sarmentosa ramosissima, ramis patentibus decussatis puberulis vel glabratis, foliis ovalibus acuminatis rarius apice rotundatis sæpe mucronulatis basi rotundatis vel rarius subcuneatis oppositis vel rarius quasi quaternate verticellatis deciduis chartaceis nervis exceptis glabratis supra nitidis infra secus costam et 4–5-jugos nervos puberulis vel brevipubescentibus breviter petiolatis, stipulis e basi brevi lata subtruncata setaceo-apiculatis petiolum pubescentem subexcedentibus, floribus candidis extus sæpe roseo-sanguineis vel niveis fragrantibus sæpe subpendulis solitariis vel subgeminis lateralibus vel ramulos abbreviatos laterales terminantibus præcocibus subsessilibus basi bracteolatis, bracteolis glumaceis ovatis vel lanceolatis acutis imbricatis calycem excedentibus rarius quibusdam subfoliaceis, calycis urceolati limbo sæpius 8-fido lobis rotundatis rigidulo-membranaceis glabris, corolla 7–6- rarius 5-loba caduca, antheris sæpius 7–6 erectis subinclusis filamentis brevissimis, stylo bifido lobis patulis crassis lanceolato-spathulatis obtusis intus stigmatosis.

Hab. in sylvis et dumetis densis ad basim et declivia montium Serra do Alto Queta territorii Angolensis, Golungo Alto legit *Welwitsch !* no. 2572, Decembr. 1854 et Octobr. 1855 c. flor., etiam Novembr. 1855 et Junio 1856 c. fr.; in Nigritia ad Onitsha legit *Barter !* no. 1249 (suffrutex subscandens, baccis albis); etiam ad oppidum Old Calabar legit *Rev. W. C. Thomson !* no. 37, freq.

Frutex 2–5-pedalis; folia $1\frac{1}{2}$–3 poll. longa, $\frac{2}{3}$–$1\frac{1}{3}$ poll. lata. Flores pollicares vel sesquipollicares; bacca $\frac{1}{4}$–$\frac{1}{3}$ poll. diam.

15. Coffea racemosa, Lour. Fl. Cochinch. p. 145, n. 2 (1790), non Ruiz et Pavon (1799).

C. ramosa, Roem. et Schult. Syst. Veg. i. p. 198. n. 10 (1819).

C. mozambicana, DC. Prodr. iv. p. 500. n. 18 (1830).

Hab. Mozambique Island, *Loureiro.*

The seeds are said to be used for coffee. I have seen no specimen.

Excluded Species.

Coffea laurina, Poir. in Encycl. Méth. Suppl. ii. p. 14. n. 15 (1811), is *Craterispermum laurinum,* Benth. Sierra Leone.

Coffea cymosa, Willd. ex Roem. et Schult. Syst. Veg. v. p. 201. n. 27 (1819), is doubtfully referred to *Chasalia Fontanesii,* DC. Bourbon.

COFFEA CAPITATA, Sieb. Fl. Maurit. Exsicc. n. 335, is *Chasalia coffeoides*, DC. Mauritius.

COFFEA DIVARICATA, Tausch in Sieb. Fl. Maurit. Exsicc. ii. n. 271, is *Chasalia divaricata*, DC. Mauritius.

COFFEA HIRSUTUS, G. Don, Gen. Syst. Gard. & Bot. iii. p. 581. n. 5 (1834), is *Cremaspora africana*, Benth. Sierra Leone.

COFFEA KRAUSSIANA, Hochst. in Flora, 1842, p. 237, note, is *Kraussia floribunda*, Harv. Natal.

DESCRIPTION OF PLATE XXIV.

Plate of *Coffea liberica*, from a specimen in the British Museum, collected by Dr. Daniell in January 1856, at Sierra Leone, where it was cultivated: the flowers have been preserved in liquid. The principal figure shows a flowering branch (natural size), with a small lump of clear gummy secretion at the apex, with flower-beds in the next axils, with flowers (some fully expanded) in the next, and with very young fruits on the lowest axils that are included in the figure.

Fig. *a* shows a cluster of three calyces, also natural size, with the calyculate upper bracteoles covering the short pedicels, the middle calyx shown after the fall of its corolla, the right-hand one with a fully expanded corolla, and the left-hand one with a young unexpanded corolla.

Fig. *b* shows a vertical section, somewhat enlarged, of the ovary and epigynous disk by a central plane perpendicular to the septum; the solitary ovules are seen to be attached near the middle.

Fig. *c* shows a pyrene as seen from the face, natural size.

Fig. *d* shows a lateral view of the same, also natural size.

Fig. *e* shows a dorsal view of a seed (natural size) cut away rather obliquely towards the base so as to expose the embryo with its inferior radicle.

XI. *On the Origin of Floral Æstivations. With Notes on the Structure of the Cruciferous Flower, on that of* Adoxa, *and on the Corolla of* Primula. *By the Rev.* G. Henslow, *M.A., F.L.S., F.G.S.*

(Plate XXV.)

Read June 1st, 1876.

Introduction.

THE idea of endeavouring to trace out any laws that may exist amongst floral æstivations arose in my mind from observing the large number of *diagrams* given in Le Maout and Decaisne's 'Descriptive and Analytical Botany,' in which the æstivations of about 250 genera of Dicotyledons and of 50 of Monocotyledons are diagrammatically expressed. I therefore proceeded to draw up an enumeration of all the different kinds, and to ascertain what percentage each had amongst the genera, and what connexions there might be amongst those different kinds. I then examined a number of living flowers of several genera, but soon found my work had been to some extent inefficient as based upon very insufficient data *.

So far from each diagram given being the sole example or even always typical of a genus, I found it to be the commonest thing for a species to have a very considerable amount of variation, as will be seen at the close of this paper. As an example, the diagram of *Primula*, p. 529 (Engl. ed.) †, is not the only kind, as this genus can boast of at least eight varieties in the Primrose alone. Again, the diagram of the male flower of *Hydrocharis*, p. 754, does not correspond with the figure of the flower given there, in that the inner whorl of the figure is "tristichous," while it is represented as "convolute" in the diagram. Lastly, two diagrams of *Hermannia* are given on p. 284, as if it were an unusual occurrence for a flower to have its whorls running spirally in opposite directions, whereas it is an extremely common occurrence. Hence, if any one should be led to imagine these diagrams to be in all cases characteristic or the sole kinds of æstivation peculiar to each genus respectively, he will be much mistaken. It may be observed, however, that nothing is said respecting them whatever, as to whether they *do* represent typical forms or not. On the other hand, the æstivations of many genera are remarkably constant, such as the universally "convolute to the left" corolla of *Myosotis*; or again, the valvate calyx with contorted corolla of Mallow, though even here the "imbrication" may be either to the right or left; and when this is the case, it may become, as Robert Brown pointed out, a valuable diagnostic character.

* The draught of this paper was made on recovering from a long illness, when I had but few opportunities of testing the conclusions given from the study of the diagrams alone. I, however, give these conclusions, because the reader will be able to refer to the diagrams in that excellent work, and because the deductions made from a comparison of those diagrams is generally very similar to that derived from the examination of the variations in the flower-buds of living plants.

† The references to *pages* throughout this paper always refer to Le Maout and Decaisne's work.

Little attention, indeed, appears to have been paid to æstivations until that eminent botanist called attention to their importance *. Since then nearly all text-books describe the principal forms, but without tracing any or but slight connexions between them.

If we turn to our latest authorities, we find Le Maout and Decaisne, for example, devoting two pages (86, 87) to the subject in describing, as usual, the different kinds, and also attempting to explain the "papilionaceous" and "cochlear" by, as I believe, a wrong application of the "quincunx;" while in Sachs's 'Text-book of Botany,' "æstivation," "imbricate," "contorted," and "valvate," are words conspicuous by their absence from the index as well as from the text. Many diagrams occur in that work; but the subject of æstivation seems to have been totally ignored.

The laws of phyllotaxis have to some extent been adapted to the floral whorls, more especially and obviously to the quincuncial or $\frac{2}{5}$ plan. The very frequent occurrence of this latter amongst sepals and petals is of itself a sufficient indication that phyllotactical laws are in certain cases applicable—as also the fact that the outer whorls of flowers are in some cases composed of many parts and spirally arranged, especially when there is no manifest "break" between the whorls, as in *Calycanthus*, *Cactus*, &c. In these cases the $\frac{2}{5}$, $\frac{3}{8}$, $\frac{5}{13}$, and even $\frac{8}{21}$ arrangements may be detected.

II. The Forms of Æstivation,

The following include those usually described, as well as one or two in addition.

1. *Distichous equitant, or the* $\frac{1}{2}$ *arrangement* in which one of the two opposite parts overlaps the edges of the other, as in *Papaver* (Tab. XXV. fig. 1).

The *half-equitant* is a modification of this, in which one edge of each part overlaps one of the edges of the other part respectively, as in the calyx of Poppy and the corolla of *Circæa* (Tab. XXV. fig. 2).

2. *Tristichous or the* $\frac{1}{3}$ *arrangement.* This is especially characteristic of Monocotyledons. It may be observed that it is identical with the "imbricate proper" when the whorl has only three parts, so that the first overlaps the second, and the latter overlaps the third, which last also underlies, with its opposite edge, the first (Tab. XXV. fig. 3).

3. *Pentastichous, quincuncial or* $\frac{2}{5}$ *arrangement*, in which the parts of the whorl correspond with those of one projected "cycle" of that plan (Tab. XXV. fig. 4).

4. *Half-imbricate.*—I apply this term to a large number of instances ranging from complete regularity to such extremely irregular forms as the corollas of the Violet, the Pea, and the Snapdragon. It is produced by a slight modification of the quincuncial—namely, by the edge of the second part being overlapped by instead of itself overlapping the fourth part (Tab. XXV. fig. 5).

5. *Imbricate proper*†, in which the parts of a whorl overlap each other in succession,

* A short summary of the history of the nomenclature of æstivations has lately appeared from the pen of Prof. A. Gray, in the American Journal of Sciences and Arts, vol. x. Nov. 1875, and is reprinted in the Journal of Botany, new series, vol. v. p. 53.

† I call this "imbricate proper," as the word "imbricate" is also used technically for an indefinite number of parts, as in the scales of *Calycanthus* &c., which overlap like tiles on a roof. Linnæus appears to have included all these forms (viz. 3, 4, 5, and 6) under this term (see Prof. Gray's paper *l. c.*).

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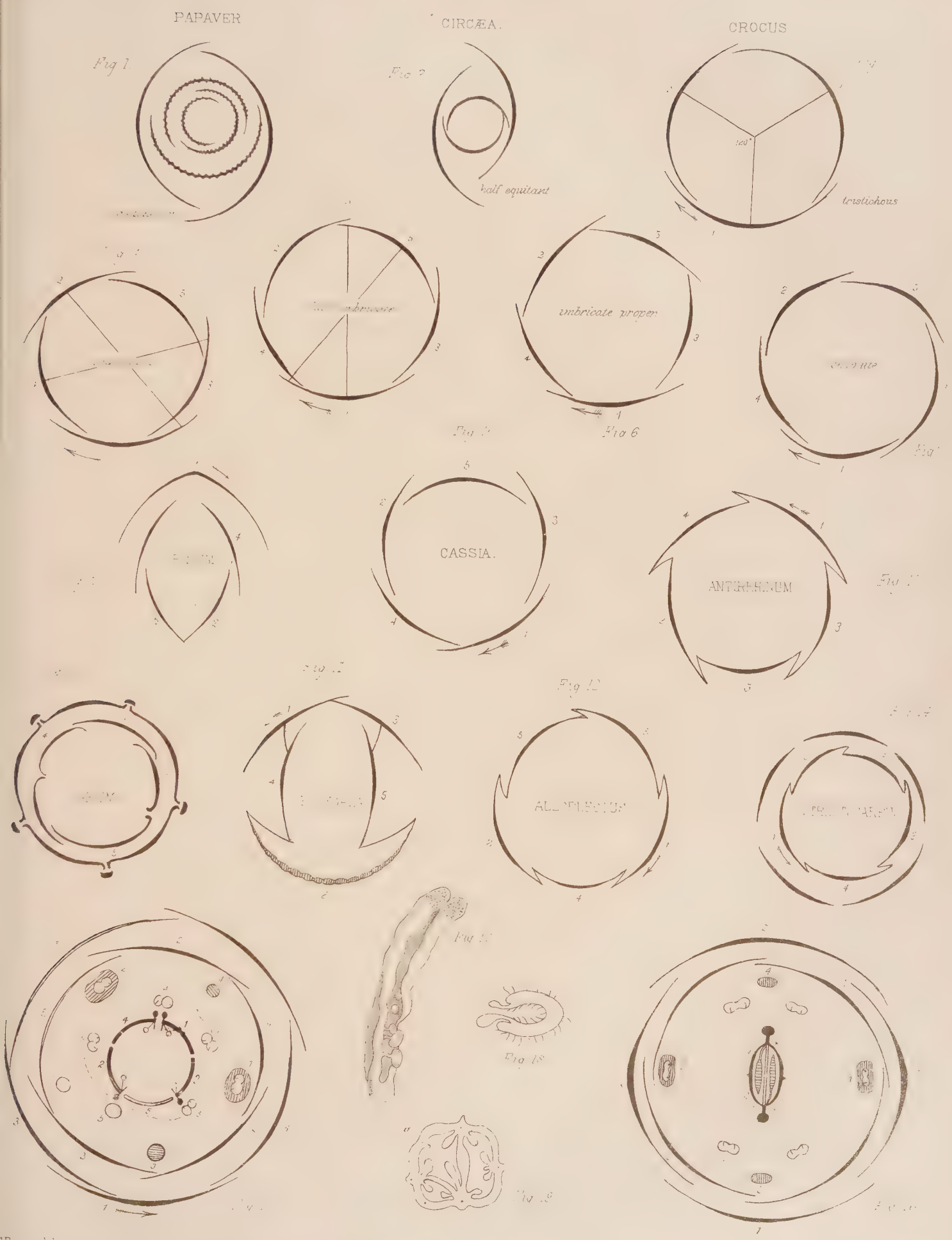

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so that one, the first, is entirely outside the adjacent parts, while the last is entirely within. This is deduced from the last by allowing the third member to slip one edge under the fifth, in addition to the second being under the fourth (Tab. XXV. fig. 6).

6. *Convolute and contorted.*—In these each part of the whorl overlaps one adjacent part by one of its edges, and is in turn overlapped by the other adjacent part (Tab. XXV. fig. 7). This is deduced from the preceding in a similar manner to that—namely, by passing an edge of the first part under that of the third.

Hence it will be seen that Nos. 3, 4, 5, and 6 are closely connected, and may be briefly expressed by saying the half-imbricate is formed from the quincuncial by having the 4th member over the 2nd, the imbricate proper from the half-imbricate, by having the 4th over the 2nd and the 5th over the 3rd, the convolute from the imbricate proper by having the 4th over the 2nd, the 5th over the 3rd, and the 3rd over the 1st *.

7. *Valvate.*—In this the edges of adjacent parts touch only, but do not overlap. The two main varieties, besides the simply valvate, where the edges just touch, are:—

Induplicative, where the edges are rolled inwards; *reduplicative*, where the edges are rolled outwards.

8. *Straight or open.*—In this the parts of the whorl are not sufficiently developed to meet even as in valvate, and therefore the æstivation may be said to be indeterminate.

III. The Degrees of Frequency of the various Kinds of Æstivation.

The following percentages are deduced from Le Maout and Decaisne, as stated above.

I. Dicotyledonous Angiosperms.

A. Imbricative.

1. Equitant Calyx	occurs about	4 p. c.
,, Corolla	,,	12 ,,
2. Tristichous, Calyx, or Corolla . . .	,,	11 ,,
3. Pentastichous, Calyx, with Cor. various	,,	24 ,,
,, Corolla, with Calyx ,,	,,	10 ,,
,, both Calyx and Corolla	,,	14 ,,
4. Half-imbricate (excluding Papilionaceous and cochleate varieties) . .	,,	15 ,,
5. Imbricate proper, Calyx, apparently very rare, as in *Cyclamen*, p. 529.		
Imbricate proper, Corolla	,,	9 ,,
6. Convolute, Calyx, apparently rare.		
,, Corolla	,,	16 ,,

* Prof. A. Gray's paper is chiefly directed to the settlement of the proper term for this kind; and he concludes that "convolute" is preferable to "contorted," as the latter does not differentiate corollas with a torsion, the petals of which have each a spiral axis, from those with no torsion, or whose axis is erect. A third term, "obvolute," would, he observes, claim priority as having been used by Linnæus; but it has not been in common usage. As the Professor concludes with the words, "I should hope rather than immediately expect that this use would become general," I have the satisfaction of fulfilling those expectations immediately; for although this paper was written before Prof. Gray's was published here, and I had adopted the word "contorted," I have altered it in every case to "convolute," in accordance with his wish.

B. Valvative.

7. Valvate (including varieties).		
Calyx valvate, with Corolla various .	occurs about	11 p. c.
Corolla valvate, with Calyx various .	,,	6 ,,
8. Straight or open.		
Calyx open, with Corolla various .	,,	28 ,,
Corolla open, with Calyx various .	,,	5 ,,

II. Petaloid Monocotyledons.

1. Equitant is represented in 3 genera only besides Grasses.		
2. Tristichous, outer perianth whorl . .	,,	40 ,,
,, inner perianth whorl . .	,,	60 ,,
3. Pentastichous occurs in *Paris polyphylla*, p. 859.		
6. Convolute, represented in 4 genera only.		
7. Valvate	,,	20 ,,
8. Open	,,	30 ,,

IV. Remarks on the preceding Varieties of Æstivation.

1. *Equitant.*—The proportion of flowers which have equitant whorls, either entirely, when one member of the pair is embraced by both the edges of the opposite member, or half-equitant, in which each of the pair overlaps one edge of the other, occurs in corollas about 12 p. c. and in calyces about 4 p. c., as calculated from the diagrams of Le Maout and Decaisne. Probably this is not far from being correct.

With regard to the origin of this kind, I am inclined to think it is due to a reduction of parts from the tristichous or pentastichous arrangements, and in some cases may be a retention of a primitive condition. If one member of a tristichous whorl be suppressed, the other two will most probably become equitant, as flowers almost * invariably arrange their members either radially or bilaterally symmetrically. Such, I suspect, will account for this æstivation in poppies, for example, where the calyx is half-equitant and the corolla equitant (Tab. XXV. fig. 1). *Papaver* and its nearest allies of the tribe *Eupapavereæ* are usually binary or quaternary in their perianths, though whorls of threes are not wanting, and seem to point to their ancestral character, which is retained in *Romneyeæ*. Moreover *Papaver orientale* not unfrequently develops a third smaller sepal, which may or may not be accompanied by a trimerous corolla, which I take to be due to atavism.

If this theory be correct, the ancestors of poppies were trimerous; but by the arrest of one part in the calycine and one in each of the corolline whorls, these have become dimerous and equitant in æstivation.

* There are a few rare instances, due to insect agency, such as *Polygala chamæbuxus* and *Phaseolus*, which are, so to say, "distorted." I use the word *symmetrical* here in its popular, not botanical sense, as usually restricted, though Sachs applies it thus. The term *zygomorphic* has been used to express bilateral symmetry, and, if generally adopted, would avoid much confusion.

Or again, if we start with a quincuncial arrangement, the equitant condition is arrived at by suppressing either the first or fifth member. This, I think, has probably been the case with *Actæa* (p. 186) and *Adoxa* * (p. 474), as well as with the *Cruciferæ* †. *Circæa* (Tab. XXV. fig. 2), however, I am inclined to think owes its equitant æstivation either to an original dimerous symmetry derived from opposite leaves, or else it may be due to "symmetrical reduction" from a tetramerous type which prevails in the same order (*Onagraceæ*) to which it belongs.

If the equitant æstivation is presumably derived from a quincuncial whorl of five parts, by the arrest of one, the four remaining will probably be wholly equitant at first; but they may undergo further changes. If it be the result of a convolute æstivation, then the remaining pairs will more likely be half-equitant. Thus, if *Circæa* be derived from a tetramerous type with convolute petals, as occurs in *Epilobium*, by the arrest of two opposite parts, then it will be seen how each part of the remaining pair will overlap the other reciprocally, and the resulting æstivation will become half-equitant (Tab. XXV. fig. 2).

I would not, however, venture to lay very much stress on this supposed difference in the origin of half-equitant as compared with equitant whorls; for the overlapping of another by the edge of any part may be simply due to some slight advantage in growth quite irrespective of any cause arising from antecedent conditions—as, indeed, may be the case with the calyx of *Papaver*, which is half-equitant, though, as I presume, its dimerous character is derived from a tertiary type.

2. *Tristichous.*—This will be seen to be identical with an imbricate-proper æstivation when the whorl consists of three members only. It is very common in the perianth-leaves of Monocotyledons, occurring in the outer whorl about 40 p. c., and in the inner whorl about 60 p. c., as deduced from the diagrams of Le Maout and Decaisne. This possibly would require some modification; for I found the convolute æstivation also very common, as in about one third of the flowers of *Crocus* examined. This kind is represented by those authors as occurring in only four genera. In a pound of dates I found the percentage of the inner whorl of the perianth as tristichous to be 82, and as convolute 18. The outer whorl is gamophyllous, and reveals no succession of parts.

The origin of the prevailing ternary arrangement in Monocotyledons I take to be simply due to the fact that it does *not* arise out of opposite leaves, which latter, as I have shown elsewhere, gives rise chiefly to the pentastichous arrangement (Trans. Linn. Soc. sec. ser. vol. i. p. 37), so common in Dicotyledons; hence, as the usual phyllotactical requirements demand three leaves for every projected circle, and the floral requirements demand an alternation of position in the successive whorls, so by these two effects there issues the usual alternation of groups of threes.

In Dicotyledons there is a group of orders with a ternary arrangement prevailing amongst them (*Magnoliaceæ*, *Anonaceæ*, *Menispermaceæ*, *Berberidaceæ*), associated with a few genera or orders having a large number of imbricated parts in their floral whorls (*Dilleniaceæ*, *Calycanthaceæ*, *Nymphæaceæ*, &c.). When the whorls are in

* See Note B, p. 194, on the variations of the symmetry of the flowers of *Adoxa*.

† See Note A, p. 191, on the origin of the arrangement of the parts of a cruciferous flower.

threes in these orders, I believe it to arise as just stated, and as is more fully explained further on (Note C, p. 194) from phyllotactical considerations; that is, a prolonged spiral, instead of furnishing whorls corresponding to cycles, as in *Aconitum*, is simply broken up into decussating whorls of threes.

3. *Pentastichous or Quincuncial.*—This arrangement is one in which the parts of a whorl constitute one cycle of that leaf-order. Each successive member is at an angular distance of 144° from the next in order. It appears to be the commonest in Dicotyledons, obtaining either in one, two, or more whorls of a flower, and, from the diagrams of Le Maout and Decaisne, occurs about 50 p. c. This deduction is quite corroborated by observations on individual plants; for in the flowers *e. g.* of Primrose * (which shows eight if not more varieties of æstivation) the pentastichous was about 40 p. c. Similarly is it with *Viburnum tinus*.

What I have said upon the origin of alternate leaf-arrangements in my paper referred to above, fully accounts for this plan being the commonest among Dicotyledonous Angiosperms. Indeed I would venture to call it one of the fundamental plans, as giving rise to at least three others, if not more, such as the half-imbricate, imbricate proper, convolute, and possibly in part the equitant.

4. *Half-imbricate.*—I apply this term to a very common arrangement, which does not appear to have been at all recognized before, but which is nevertheless a very important type of æstivation. It is deduced from the pentastichous by the 2nd member of that kind having one of its edges passing under the 4th, and is not only the first step towards the imbricate proper, and thence to the convolute, but will also explain the æstivation of many irregular flowers, such as the "papilionaceous," that of the *Cæsalpineæ*, and the "cochlear" †, which, too, can be thus accounted for by a simpler method than is usually applied, and moreover a perfectly natural one, as it exists abundantly amongst floral whorls.

In the percentages deduced from the diagrams of Le Maout and Decaisne, that of this kind does not appear very high (16 p. c.). An examination of many flowers leads one to think it should be somewhat higher, as, *e. g.*, in *Laurustinus* it amounts to nearly 80 p. c., though in the Primrose it is certainly rare; similarly in *Ribes* it only amounts to about 10 p. c.

With regard to the papilionaceous corolla, if we consider the standard as No. 1, one of the keel-petals as No. 2 (of a quincunx), *which now passes under the wing*, *i. e.* No. 4, the wing on the opposite side of the median line will be No. 3, while the remaining keel-petal will be No. 5, coherent with No. 2.

* The diagram given by Le Maout and Decaisne of the Cowslip (miscalled Primrose), on p. 529, has both the calyx and corolla according to the imbricate-proper æstivation, and not pentastichous, which is much the most characteristic form. See Note D, p. 195.

Since this paper was sent to press, my attention has been called to Dr. A. W. Eichler's 'Blüthendiagramme,' in which he observes that this form is found both in regular and irregular flowers, and he gives a diagram of it for *Adoxa*, p. 270, and *Valeriana officinalis*, p. 275; but he retains the name "cochlear." This I purposely avoided, as it has only a specific and not generic value.

† In the translation of Le Maout and Decaisne the word "cochleate" is used instead of "cochlear," which is the correct term: the former is descriptive of a spiral shell, and would be applicable to the coiled legume of *Medicago*.

Le Maout and Decaisne endeavour to explain the structure differently, by conceiving No. 1 to be one of the wings, No. 2 the other wing, No. 3 a keel-petal, No. 4 the standard, and the remaining keel-petal No. 5. They thus derive it from the quincunx by removing the standard from being entirely *within* to a position entirely *without* the rest (fig. 466, p. 87). Similarly with regard to the æstivation of the *Cæsalpineæ* as represented by the diagrams of *Cassia* and *Cercis* (p. 367), though in these some confusion in the explanation is made by those authors; for in describing (on p. 87) these diagrams, they say,—" The standard retains its normal position [*i. e.* within the others], and the quincunx is properly formed." But in reference to the diagrams given in p. 367, this is clearly not the case. Both in that of *Cercis* and that of *Cassia*, if we take the outermost of the two anterior petals as No. 1, then No. 2 (whether the spiral be supposed to turn to the right, as in *Cassia*, or to the left, as in *Cercis*) is in neither case external also, as it ought to be for a quincuncial or pentastichous arrangement. If, however, we take, as I propose, the exterior anterior petal as No. 1, then the internal petal as No. 5, both the above kinds fall under this type, which I call half-imbricate.

It will be seen that No. 1 is not the same petal in both the papilionaceous corolla and that of these two genera of *Cæsalpineæ*. That this difference is of no relative importance will be shown hereafter. It may be remarked here, however, with regard to the standard not being identical with the fifth (internal) petal of *Cassia*, that the wings of the former lie over the keel, while in the latter genus it is just the reverse. This would seem to show that the papilionaceous resemblance is apparent only and not real.

The calyx in *Cassia* is represented as quincuncial, that of *Cercis* " open " and therefore indeterminate.

I recommend this interpretation as doing far less violence to the fundamental quincunx than that hitherto suggested; in other words, it is acquired by a simple alteration of position *of one edge only* of one petal. It may be observed, too, that it is obtained by regarding the parts of the spiral as running in the reverse direction to that according to the former method of regarding it.

This type of æstivation will also account for the so-called " cochlear," as of the Snapdragon (Tab. XXV. fig. 10, and Le M. & D. fig. 468, p. 87, in which the numbers there given should be exchanged respectively as follows, viz. 1, 5, 4, 3, 2 should be written instead of 1, 2, 3, 4, 5). Thus by retaining the innermost (anterior) petal as No. 5, and by merely shifting No. 2 partially under No. 4, we obtain the æstivation as illustrated by the diagram.

Another illustration of the half-imbricate in connexion with the quincuncial will be found in the diagrams of *Scrophularineæ*. The calyx of *Scrophularia* (p. 585) is strictly quincuncial: the exterior sepal, No. 1, is posterior *; but if this be compared first with the diagram of *Linaria* (p. 584), it will be seen that the 2nd sepal (the right anterior) now passes under the 4th (or the right), the spiral being right-handed †; and the æstivation of the calyx is therefore half-imbricate. It is similar to the calyx of *Paulownia* (p. 584); only this spiral is left-handed. But now comparing these with the calyx in the

* The diagram is wrongly placed. The left-hand exterior sepal is the posterior one in reality.

† On the distinction between right- and left-handed spirals, see below, note, p. 186.

diagram of Snap-dragon, p. 583, the 1st sepal is no longer the posterior one but the left anterior; the spiral is left-handed; and the posterior sepal is the 5th, and completely within the others. The corollas of all three genera have the same æstivation, and are constructed on this plan, which I call half-imbricate, having, at least most commonly, the 5th petal as the anterior one.

It is rare to find any other part than the 5th in the anterior position of the zygomorphic whorl, when its æstivation is half-imbricate. There is, however, one case figured by Le Maout and Decaisne, viz. the diagram of *Streptocarpus* (p. 598), in which the 4th petal is the anterior one. It is also thus in *Azalea* and *Rhododendron*, in which the 5th petal (always the single petal, which is entirely within the others) is the posterior one. Lastly, in *Pelargonium* alone all these arrangements may be found.

The above shows that no necessity can be seen for No. 1 of a whorl being always the same in position and therefore always homologous.

I have already remarked that this arrangement furnishes conditions varying from perfect regularity in the whorls to extremely irregular ones. A few references to the pages of Le Maout and Decaisne will illustrate this.

1. Corollas regular or very slightly irregular:—

Pittosporum, p. 248; Rue, p. 317; *Parnassia*, p. 403; Elder, 481.

2. Corollas partially or decidedly irregular:—

Moringa, p. 235; *Dictamnus*, p. 316; Horsechestnut, p. 357; *Cassia*, p. 367; *Rhododendron*, p. 516; Henbane, p. 578; *Vitex*, p. 615.

3. Very irregular corollas:—

Pansy, p. 241; *Lathyrus*, p. 369; Snapdragon, p. 87; *Lamium*, p. 620.

Irregular and zygomorphic flowers are sometimes produced without any departure from the quincunx; for it should be observed that both the quincuncial and the half-imbricate æstivations can be divided symmetrically into two similar halves (as represented in Tab. XXV. figs. 4 and 5) by median lines. Thus is it with *Polygala* (Tab. XXV. fig. 11), which somewhat resembles the papilionaceous; but the æstivation is simply quincuncial and without any modification. Similarly amongst gamopetalous corollas the diagrams given of *Alloplectus*, p. 597, as well as that of *Achimenes*, p. 596, and *Adhatoda*, p. 606, though possessing irregular bilateral flowers, have yet their petals arranged on the quincuncial plan.

Irregular flowers with a quincuncial æstivation would seem to be comparatively rare; and when it does occur the various parts are not always homologous. Thus in *Ramondia*, p. 600, *Alloplectus*, p. 597, and *Achimenes*, p. 596, it is in the 4th part, while in *Stilbe*, p. 613, it is in the 3rd part, and in *Myoporum*, p. 610, it is in the 1st part, which respectively occupy the anterior position.

5. *Imbricate proper.*—In this æstivation the parts of the whorl may be three in number, as in the tristichous; four, as in Holly, p. 339, and *Euonymus*, p. 342; or more commonly five or more. The parts overlap one another in succession, so that the first is wholly exterior, and the 'last' (which is really the third of the original quincunx from which it is derived) is entirely within the spiral. Le Maout and Decaisne number the parts in succession, fig. 463, p. 86; but this is not, nor can it possibly be correct, at least in accordance with phyllotactical principles; for if it were, we should have *five* parts

in a single projected coil or circle, which can only arise from the series $\frac{1}{4}$, $\frac{1}{5}$, $\frac{2}{9}$, $\frac{3}{14}$, &c. I observe Prof. Gray also notices the mistake of those authors, which occurs also in other text-books. If, however, we proceed from the last-mentioned æstivation, or the half-imbricate, in which the 2nd part lies under the 4th, and place the 3rd under the 5th, we at once obtain the present kind.

In the percentages deduced from the diagrams of Le Maout and Decaisne, it will be seen that this kind is much less common (only 9 p. c.) than the preceding; and what appears true for genera is also true for flowers of individual plants. Thus Laurustinus and Primrose give the percentage of imbricate proper as only 10.

6. *Convolute.*—As the last is derived from the half-imbricate, so this is obtained from the imbricate proper, by placing the 1st part under the 3rd of the quincunx; so that if we write the connexion of these three kinds successively, it will appear as follows:—starting with the quincunx, if we place the edge of No. 2 under No. 4, we obtain the half-imbricate; next, place the edge of No. 3 under No. 5, and we get the imbricate proper; and lastly, in addition to these, place the edge of No. 1 under No. 3, and the convolute is secured.

As long as the convoluted petals are erect and their median lines vertical there will be no torsion; but in some cases the apex appears as if it were artificially twisted, as in Mallow, Flax, &c. In these cases the word "contorted" can be applied either with or without "convolute" as well.

In turning to the percentages deduced from the diagrams of Le Maout and Decaisne, it appears that in corollas of different genera the number recorded gives the convolute variety a position of 16 p. c.; and in comparing this with the percentages of the same kind, deduced from flowers of the same species, as of the Primrose, it amounts to 15 p. c., or almost the same.

7. *Valvate.*—Of this kind of æstivation, with its two varieties induplicative and reduplicative, little need be said. They are comparatively rare both among sepals and petals. With regard to the origin of it, I believe, in possibly the majority of instances, it is due to a degradation from the imbricative kinds, using that term in a general sense. It is at least probable in all instances where the flower is presumably due to a spiral phyllotaxis. The diagram of *Geum*, p. 382, appears to afford an instance of a transition from the quincuncial to the induplicative in the petals, while the calyx has assumed a reduplicative form. I have reproduced this diagram in Tab. XXV. fig. 13.

In some cases where the flowers are dimerous or tetramerous, a symmetry which has probably risen from a similar opposition in the foliage-leaves *, it is also probable that no spiral arrangement has ever intervened. This may explain the fact of *Clematis* being nearly the sole genus (*Naravelia* is properly a subgenus only) of *Ranunculaceæ* which has opposite leaves and tetramerous flowers with a valvate calyx. Similar is it with the genera of *Oleaceæ*, as the Lilac, the sepals of *Epilobium*, of *Rhizophora*, &c. An illus-

* I hope to develop this idea on a future occasion. I would just call attention to the significant fact that of the genera of *Rosaceæ*, comprising 71 in all, as recorded in the 'Genera Plantarum' (Benth. and Hook.), three only have opposite leaves, and these three are alone characterized as having tetramerous flowers, viz. *Rhodotypus*, *Eucryphia*, *Coleogyne*.

tration of opposite foliage-leaves coalescing in venation in a valvate manner is seen in some species of shrubby *Veronicæ*.

Of course there are instances of a valvate calyx accompanied by an alternate arrangement in the foliage-leaves, such as *Malva*. These, as also all "open" kinds of æstivation, may be and probably are due to degradation, in consequence of which the parts only grow just sufficiently large to meet in the former case but not overlap, or else, as in the latter instances, to fall short of one another altogether, as in the *Umbelliferæ*.

V. Reversal of the Spiral.

A peculiar feature to be noticed is the frequent reversal of the direction in which the parts of successive whorls run, whether of the corolla in being different from the calyx, or the inner whorl of a monochlamydeous perianth from the outer. Of the 35 diagrams in Le Maout and Decaisne which have both calyx and corolla quincuncial, two have the calyx right-handed and the corolla left-handed. On the other hand, four have the calyx left-handed, while the petals form a right-handed spiral. All the rest have the calyx and corolla either right-handed or left-handed together *.

In examining several flowers of the same species, as in other matters, so in reversal, I found many single kinds of plants furnishing this phenomenon, as Crocus and *Malva sylvestris*, in which the right-handed and left-handed contortions were in equal proportions numerically.

VI. The numerical Order of the Parts of Whorls.

In examining the 34 instances of dicotyledonous Angiosperms, where both calyx and corolla are arranged on the quincuncial plan, the first petal of the corolla was found to be in 13 instances between the 1st and 3rd sepals; in 11 instances between the 1st and 4th sepals; and in 1 instance between the 5th and 3rd sepals. In all these cases the imaginary spiral line would be in the same direction, though not continuous from the 5th sepal to the 1st petal.

In 9 instances the spiral has to be *retraced* to discover the 1st petal. Of these latter in 3 instances the 1st petal lies between the 5th and the 2nd sepal, and in 6 instances

* With regard to the direction of the spiral, I always signify as *right-handed* the parts of a whorl the sections of which, as represented by a diagram, overlap on the right side, *as seen from the centre, i. e.* corresponding with the movement of the hands of a watch. I find this method more convenient for *diagrams* than the reverse, which is employed in the terms *sinistrorse* and *dextrorse* for spiral climbers. In that case it is more convenient to regard the spectator as being on the outside of the climber. Prof. A. Gray (*l. c.*) says:—"I note with satisfaction that Bentham and Hooker use these terms to signify from left to right or from right to left of a person supposed to stand outside of a closed bud, which is surely the natural position of the observer." This is without doubt perfectly true *for a bud*, but it is not *for a diagram*, which is a transverse section of a bud. In this case it is "natural" for the eye to rest on the centre. People invariably regard the hands of a watch as going from left to right; yet if instead of regarding yourself in the middle of the watch, you remember that you are outside of it, then the hands go from right to left when passing from 3 to 9 o'clock.

There appears to be some confusion in Le Maout and Decaisne's work; for they describe their diagrams, p. 80, of phyllotaxis as left-handed, though they are really right-handed if traced from the periphery to the centre; yet the descriptions of the two convolute corollas of *Hermannia*, p. 284, correspond to the method I have adopted; compare also the diagram of *Dianthus*, p. 256, which, again, is contrary to the latter, and is left-handed, though described in the text as right-handed.

between the 2nd and 4th; but in no instance amongst the diagrams given does it pass beyond two sepals. Lastly, in 7 instances, as stated above, the spiral of the corolla was completely reversed in direction from that of the calyx.

Similarly in turning to Monocotyledons we find, of the two whorls of the perianth, that some genera have both revolving the same way, others have one whorl the reverse of the other. Moreover the point where the second whorl begins in either case is as variable as in Dicotyledons. Thus, of those genera where both whorls revolve in the same direction, *Pinanga*, p. 812, and *Commelyna*, p. 568, commence the inner whorl with their 1st part between the 2nd and 3rd leaves of the outer whorl, both being right-handed spirals. In *Juncus*, p. 864, *Phormium*, p. 844, *Lapageria*, p. 856, and *Alisma*, p. 800—all being left-handed spirals—the 1st leaf of the inner whorl lies between the 1st and 2nd of the outer.

Again, in *Colchicum*, p. 850, *Fritillaria*, p. 843, while both whorls revolve to the right, the inner commences with its 1st leaf between the 3rd and the 1st of the outer. In *Butomus*, p. 798, Snowflake, p. 786, and *Toffieldia*, p. 851, the inner whorl commences diametrically opposite to the last leaf of the outer (that is, it lies between the 1st and 2nd leaf of that whorl), and moreover is in these three reversed in its spiral direction. In *Asparagus*, p. 859, the 1st leaf of the inner whorl lies between the 2nd and 3rd; while, lastly, in *Tradescantia*, p. 868, and the Pineapple, p. 766, it lies between the 1st and 3rd.

These statements clearly show that there is no single law causing a similarity of order in every case. On the contrary, the two whorls seem most capriciously arranged, the only common character being that in all flowers of two whorls to their perianth these should have their members alternating in position.

The preceding having been deduced from the diagrams of genera, I examined several species, and found that such variations as are here represented in different genera could be all illustrated by the flowers of a single species, as of the Snowdrop, Crocus, &c. I, however, retain the above paragraphs as referring to the diagrams, which will therefore furnish the reader with abundant illustrations.

VII. On the Causes which determine the various Kinds of Æstivation.

1. *Regular flowers.*—If the parts of a whorl are all on the same plane, it appears to be quite uncertain as to which member of the whorl shall be developed as the first or outermost, and that, if a calyx or corolla be both quincuncial, although theoretically their members are spirally arranged, yet practically No. 1 of the corolla may be any one of the five petals, and by no means necessarily as near to 144° as possible from the fifth sepal. This may be due to the fact that as the internodes are suppressed the nourishment is not only equally distributed over the circumference of the receptacle, but nearly or quite as equally in *time*, so that it is, so to say, a mere chance which part of a whorl gets the first start. Some slight differential impulse seems to occur with the first five kinds of æstivation; but with the convolute, valvate, and open no member can be called the first at all.

As in a single whorl the order of development of its parts is not always in accordance with the theoretically spiral arrangement, and still less is there any connexion between the

whorls by a continuous spiral growth, so also, in the order of development of the whorls themselves, it is by no means always true that they appear in succession acropetally.

Thus, as a consequence of a flower always terminating an axis, it is the fact that not infrequently there is subsequent intercalation of whorls exterior to some already formed. Thus in *Sileneæ* "the first whorl of stamens which appears is opposite the sepals, while the second is produced opposite the petals, and (according to M. Chatin, but my own observations scarcely corroborate the statement) *exterior* to the first-produced whorls"*. As far, however, as *Stellaria holostea* is concerned, the stamens opposite the petals seem to me to be intercalated *between* the first-formed stamens; so that the andrœcium forms one circle only. The petals, however, are decidedly later than both sets of stamens, the latter having attained considerable dimensions when the former consists of minute semicircular plates. This subsequent intercalation of whorls is perhaps due to what one may call "developmental energy" being stopped in its axial course, and, thus diverted, evincing itself by lateral or lower outgrowths. This also helps to explain the acrofugal order of expansion in *Adoxa* (see Note B, p. 194).

2. *Irregular flowers.*—There is, at least, a presumable probability, based upon what is known regarding the mutual adaptation of flowers to insects, that all irregular flowers have originally arisen by such adaptations, and that the varieties called "peloria" are reversions to the regularity of the primitive type †. Now, in order to become irregular, one obvious process is the greater development of one or more parts of a whorl, often at the expense of the others, which remain more or less dwarfed; so that it would be presumable *à priori* that irregularity would determine which part or parts should arise first from the receptacle. But this does not always appear to be the case, though at present I am not aware that any law has been discovered which regulates the order of growth. The fact that any adult part is larger than another part does not necessarily imply that it *started* first. Thus is it often with those anthers which appear first, and far outstrip the petals in size, as in *Stellaria*; yet the petals, when adult, often exceed the stamens immensely, as in the last-named genus and many others. A like remark may be made with reference to stipules of trees, as of the beech, which in the bud grow to four times the size of the leaf to which they belong, yet soon cease to grow, when the leaf ultimately exceeds them many hundred times.

M. Chatin (*l. c.*) also observes that the polystemonous andrœcia of *Mesembryanthemum*, *Opuntia*, *Cactus*, &c. are developed centrifugally; but the inner, older members become partially arrested, and the outer are the first to dehisce their anthers.

* "Some *Alsineæ*," that author observes, "with reduced flowers, give rise only to the whorl opposite the sepals. This is the rule in *Paronychiaceæ*, where sometimes the abortion of the stamens opposite to the petals is accompanied by the abortion of the petals themselves" (Bull. de la Soc. Bot. de France, C, 1874, p. 133). *A propos* of this fact, I would observe that these and other reduced flowers are mostly, if not all, self-fertilizing; and besides the degradation of the petals, as being no longer required for attracting insects, the number of stamens gets reduced, or more or less aborted; thus is it in *Senebiera didyma*, *Stellaria media*, *Viola canina*, and other species with cleistogamous flowers; sometimes the andrœcium is even barren, as in some early-developed individuals of *Capsella Bursa-pastoris*, *Glechoma hederacea*, &c.

† The order of "emergence" of the whorls of *Linaria vulgaris* is as follows—calyx, corolla (which is quite regular and spurless at first), stamens, and, lastly, the pistil.

In *Lamium album*, as illustrated by 'Sachs's Text Book,' p. 480, although 3 sepals appear before the other two, yet the adult calyx is scarcely irregular. On the other hand, the 5 petals appear together as equal-sized papillæ; the two posterior soon far outstrip the others, then arching over them protect the anthers even from a very young condition. The anterior petal in the adult stage is two-lobed, and might give rise to the impression that the lip was composed of two parts, whereas the history of its development reveals the fact that it is really single, while the "hood" is double. This is also corroborated by the fact that two vascular bundles run side by side between the two posterior and shorter stamens. In *Ajuga reptans* a converse process takes place, in that the posterior pair of petals soon become arrested, and the lip now grows rapidly, arches over, and protects the andrœcium just as the hood does in *Lamium*.

VIII. Varieties of Æstivation in the same Species of different Genera respectively.

Ranunculus bulbosus, or Bulbous Ranunculus.

Quincuncial	to the	right.	Occurred about	22	p. c.
,, ,,	,,	left	,, ,,	16	,,
Half-imbricate	,,	right	,, ,,	6	,,
,, ,,	,,	left	,, ,,	8	,,
Imbricate proper	,,	right	,, ,,	18	,,
,, ,,	,,	left	,, ,,	14	,,
Convolute ,,	,,	right	,, ,,	8	,,
,, ,,	,,	left	,, ,,	4	,,

Anomalous:—Corollas having 6, 7, or 8 petals variously folded, but with a general tendency to be convolute; also a few with 5 petals, but abnormally imbricated.

Viburnum tinus, or Laurustinus. On a corymb, with 125 flower-buds.

Quincuncial	to the	right.	Occurred about	23	p. c.
,, ,,	,,	left	,, ,,	24	,,
Half-imbricate	,,	right	,, ,,	12	,,
,, ,,	,,	left	,, ,,	26	,,
Imbricate proper	,,	right	,, ,,	6	,,
,, ,,	,,	left	,, ,,	6	,,

Anomalous:—Corollas with 6 petals, three instances; with 4 petals, one instance.

Primula vulgaris, or Primrose. Of 120 flower-buds examined.

Quincuncial	to the	right.	Occurred about	22	p. c.
,, ,,	,,	left	,, ,,	27	,,
Half-imbricate	,,	right	. . . . .	4	examples.
,, ,,	,,	left	. . . . .	4	,,
Imbricate proper	,,	right	,, ,,	5	p. c.
,, ,,	,,	left	,, ,,	6	,,

Convolute to the right.	Occurred about	12	p. c.
„ „ „ left	„ „	17	„

Anomalous:—Two instances with corolla 4-merous; two with 2 exterior petals, and 3 convolute within; one with 1 exterior and 4 convolute, one with 6 sub-half-imbricate petals.

Ribes coccineum, or Crimson Currant.

Quincuncial to the right.	Occurred about	50	p. c.
„ „ „ left	„ „	33	„
Half-imbricate „ right	„ „	6	„
„ „ „ left	„ „	6	„
Imbricate proper „ right	„ „	6	„

Fuchsia coccinea.

Convolute to the left.	Occurred about	67	p. c.
Imbricate proper „	„ „	27	„

Anomalous:—1 petal exterior, 1 interior, and 2 opposite and equitant—of this, two examples; one example with six petals, 8 corrugated sepals, 6 stamens, and 4 carpels.

Cheiranthus Cheiri, or Wallflower. The corollas of this plant afford a great variety of æstivations. The chief kinds are as follow:—

Imbricate-proper to the right.	Occurs about	12	p. c.
„ „ „ left	„ „	14	„
Convolute „ „ right	„ „	14	„
„ „ „ left	„ „	6	„
Anomalous:—1 petal exterior with 3 convolute	„ „	12	„
Modifications of equitant		37	„

Galanthus nivalis, or Snowdrop. Of 24 buds there were no less than 14 different ways of arrangement and order together.

In the following representations the outer whorl and numerical order are indicated by the upper figures, the inner whorl and the corresponding numerical order of its parts by the lower row of figures.

A. Examples of reversal of the spiral in the inner whorl as compared with the outer.

R. 1 2 3	Convolute to R.	L. 3 2 1	L. 3 2 1	Convolute to L.
L. 2 1 3	L. 3 2 1	R. 1 2 3	R. 2 3 1	R. 1 2 3

B. Examples of both whorls being right-handed:—

1 2 3	1 2 3	1 2 3
2 3 1	1 2 3	2 3 1

C. Examples of both whorls being left-handed:—

3 2 1	3 2 1	3 2 1
2 1 3	1 3 2	convolute.

D. Anomalous:—1 leaf external, the other 2 equitant.

CROCUS.

A. Examples of the reversal of spiral in the inner whorl as compared with the outer.

$$\left.\begin{array}{l} \text{R. } 1 \quad 2 \quad 3 \\ \text{L. } \quad 3 \quad 2 \quad 1 \end{array}\right\} \left.\begin{array}{l} \text{R. } \quad 1 \quad 2 \quad 3 \\ \text{L. } 3 \quad 2 \quad 1 \end{array}\right\} \left.\begin{array}{l} \text{R. } \quad 1 \quad 2 \quad 3 \\ \text{L. } 2 \quad 1 \quad 3 \end{array}\right\}$$

$$\left.\begin{array}{l} \text{L. } 3 \quad 2 \quad 1 \\ \text{R. } \quad 2 \quad 3 \quad 1 \end{array}\right\} \left.\begin{array}{l} \text{L. } 3 \quad 2 \quad 1 \\ \text{R. } \quad 1 \quad 2 \quad 3 \end{array}\right\}$$

B. Example of both whorls being right-handed,

$$\left.\begin{array}{l} 1 \quad 2 \quad 3 \\ \quad 2 \quad 3 \quad 1 \end{array}\right\}$$

C. Examples of both whorls being left-handed.

$$\left.\begin{array}{l} 3 \quad 2 \quad 1 \\ \quad 3 \quad 2 \quad 1 \end{array}\right\} \left.\begin{array}{l} 3 \quad 2 \quad 1 \\ \quad 2 \quad 1 \quad 3 \end{array}\right\}$$

D. Both whorls convolute to the right.

E. Outer whorl imbricate proper, inner convolute. Sometimes both to the right, and sometimes both whorls to the left.

IX. Note A.—On the Symmetry of a Cruciferous Flower.

It has been customary hitherto to refer the structure of a cruciferous flower to a binary or quaternary type, though in different ways *. But, seeing that the leaves are so generally pentastichous, I would suggest a reference to an original quinary arrangement, with a subsequent symmetrical reduction by the arrest of the fifth member of each whorl; by which it will be seen that the relative positions of the organs as they occur in a cruciferous flower can readily, but of course theoretically, be accounted for. Thus, if the sepals be supposed to be arranged quincuncially, then the external position of the the anterior and posterior sepals will immediately follow, these being numbers 1 and 2 of quincunx. (Compare the figs. 13 and 16 of Tab. XXV.) Next, assuming the 1st of the five petals to lie between the 1st and 4th sepal (for the whorls must alternate), and the 1st of an outer whorl of five stamens to lie between the 1st and 4th petals, we shall have the 1st and 2nd retained as stamens (forming the two exterior lateral and lower ones), and the 3rd and 4th (opposite the anterior and posterior sepals) arrested or represented by glands.

The next whorl of stamens arising in a similar manner, it will be seen how the 1st and 4th will form, by approximation, one pair, the posterior, and the 2nd and 3rd the other pair. Lastly, the pistil is probably composed, as has been often suggested, of four carpels; but their union, according to my hypothesis, would be as follows. The two posterior carpels, numbers 1 and 4, coalesce to form the posterior half of the pistil, while the 2nd and 3rd, uniting in front, will form the anterior half. Thus two coherent

* A summary of the various theories may be found in Le Maout and Decaisne's 'Botany,' pp. 229, 230. See also "Note sur une monstruosité de la fleur du Violier (*Cheiranthus Cheiri*, L.)," par M. P. Duchartre, Ann. des Sc. Nat., 5me série, xiii. p. 315.

margins give rise to the posterior placentas as well as the stigma opposite to them (this latter being composed of two adjacent marginal and coherent stigmas). Similarly the two anterior margins of the 2nd and 3rd carpels will give rise to the anterior placentas, with *their* combined stigmas. The four lateral margins I conceive as cohering down the middle of the valves; but their placentas and ovules are usually arrested. The stigmas, however, of these lateral margins are normally present in *Parolinia*.

That the stigmas are marginal in the *Cruciferæ* was noticed by Robert Brown (Misc. Bot. Works, i. p. 558); so that the anomaly of their position over or opposite the placentas disappears. Fig. 17, Tab. XXV. (copied from Duchartre *l. c.*), shows these marginal placentas and stigmas developed on a carpellary stamen. The same stamen also shows (fig. 18) how the replum is formed, viz. by a prolongation of the outer side of the margins, the ovules being produced at a short distance within the edge. Lastly, fig. 19 (also from Duchartre) illustrates one of many combinations of carpellary stamens, in which the kind of arrest of the placentas and ovules I have spoken of, and which I conceive takes place along the median line of each valve, is seen at *a*. It may be observed, lastly, that the dehiscence of the siliqua, indicated at * in fig. 16, is, according to the above interpretation, strictly loculicidal, perhaps the commonest of all the methods, and is thus relieved of all the abnormal appearances.

There are some fruits of the *Cruciferæ* in which the venation is conspicuous, and would seem to corroborate this view. Thus in *Lunaria* and *Iberis*, for example, the transverse and branching veins are given off from the margins of the valve, and terminate by anastomosing on the median line. In other cases, where the venation is more obscure, a translucent line may be observed down the middle of the valve, marking, as I take it, the line of cohesion.

Besides *Parolinia*, mentioned above, *Tetrapoma* has four carpels; and *Brassica* as well as *Cheiranthus* not unfrequently develop two in addition to their normal number, under cultivation.

With reference to the supposed quinary origin of the flower, it may be observed that *Capparis* † has sometimes five petals; and *Megacarpæa*, if the figure given by Le Maout and Decaisne be true, may have exactly 10 stamens.

It may be asked on what grounds do I assume the right to suppress the fifth part of each cycle. The reply is, that such symmetrical reduction from a normal and typically higher symmetry is extremely common. Thus Rue (including *Haplophyllum*), *Adoxa*, *Hypopitys*, *Potentilla*, *Tormentilla*, &c. have habitually both 5-merous and 4-merous flowers; while the petals of *Lythrum Salicaria* range from 5 to 7 in number; similarly 4–8-merous flowers are found on Jessamine, Elder, &c.

If now we attempt to account for this reduction or increase, it is only conceivable by its being done by some similar or identical arrest or development respectively in each whorl. If, for instance, we draw alternate whorls of fives, and strike out *one* part, but *any* of each whorl, it will be seen how impossible it will be to form uniformly alternating whorls of fours out of the remaining parts. If, on the other hand, each whorl be

† I allude to *Capparis*, as whatever theory he advanced for *Cruciferæ* must apply to *Capparideæ* as well.

numbered quincuncially, No. 1 of each whorl being nearest that of the preceding, and on the same side of it, and then if we strike out all those, say, numbered 5, the remaining four parts in each whorl, on closing up the gaps, instantly form regularly alternating whorls of fours. Thus, then, I conceive the cruciferous flower to have arisen by a symmetrical reduction from fives to fours—first by the arrest of development of every fifth part of quincuncially arranged whorls, then by an additional arrest of a posterior and anterior stamen of the outer whorl, as well as a partial arrest of the carpels as described above.

A botanist who accepts the idea of a Crucifer being referable to a binary symmetry, is M. Victor Meschajeff *. He regards the two stamens constituting one of the taller pairs (as also of two adjacent petals) as reversions to a primitive type, and considers that the usual free condition of the stamens is a result of dédoublement.

I would take this opportunity of expressing my belief that this is a fundamentally erroneous view. It seems, too, to agree with Dr. Masters's expression of "inseparate" as a substitute for "cohesion." If cohesion, however, be objected to as implying a previous condition of freedom which never existed in petals normally joined, so "inseparate" would seem to imply that union was prior to freedom. There could be no reasonable objection, as far as I see, to the term "inseparate," provided no explanation of the condition is implied, but simply the fact that the parts are "not separate." Dr. Masters, however, qualifies the term by saying that the parts thus described as inseparate are *not separated.* The use of this participle at once introduces a new idea, and implies the existence of some tendency *to separate* what was before joined. Now this seems quite as objectionable as the term cohesion seems to that author ('Botany for Beginners,' p. 27) †.

But, according to the laws of evolution, integration, where it exists, is always subsequent to isolation or freedom. The rare cases of "dialysis," as of *Convolvulus* and *Campanula* with free petals, or of "solution," as of *Pyrus* and umbelliferous flowers with an inferior calyx, would be cases of reversion; while, in the *Cruciferæ*, freedom of parts, except in the gynæcium, is clearly a fundamental condition, as it has no affinity with any gamopetalous order: consequently the occasional cohesion of petals or stamens in any cruciferous flower *is not a reversion but a more advanced differentiated state*, and appears to be due simply to the close approximation of the parts thus occasionally joined.

If such a flower should ever have an apocarpous pistil, *that* would be a true instance of reversion; but no case of union could possibly be such.

For the above reasons I have always looked doubtfully on "chorisis" as a principle in flowers. Doubling or an increase of number of parts is common enough, as indeed

* Bull. de la Soc. Imp. des Nat. de Moscou, 1872, no. 2, quoted in Bull. de la Soc. Bot. de France, A, 1874, p. 16.

† Dr. Masters has been good enough to give me the following comment on these remarks:—"'Inseparate' I apply to cases where separation of parts, though 'potential,' has not *yet* occurred, and wherein, if the course of development be arrested, it may never actually occur." But it is this very 'potentiality,' or tendency to separate parts, which I can only recognize as identical with atavism or reversion. Hence I think it ought not to be considered a principle of *development*, but rather a case of *retrogression*, and therefore exceptional.

occurs frequently in the *Cruciferæ* when two stamens arise from the same quadrangular or oval gland instead of a single lateral one; but this is not that one has given rise to two, but that in addition to the normal one another is present.

If, instead of regarding only the life-history of a plant *per se*, we regard it from an ancestral point of view, then "cohesion," as of the gamopetalæ, is the most correct term; for it implies that the parts *were* originally (that is, in their ancestry) free, but are *now*, in the existing descendants, coherent; whereas "inseparate" would imply that cohesion was an antecedent condition, and that there existed an ineffectual tendency to separate the parts of a whorl.

That a cruciferous flower has arisen through insect agency I have no doubt, and strongly suspect that the lateral single stamens are specially concerned in intercrossing. On the other hand, there are several of our common cruciferous plants which are self-fertilizing, such as *Capsella*, *Lepidium*, and *Senebiera*. In some of these I have often detected the pollen-tubes penetrating the stigma even in unopened buds, as in winter. These I take to be degraded conditions. In these, too, as far as can be judged from the relative heights of the stamens and stigmas, it would seem that the four taller stamens are chiefly, if not solely, concerned in self-pollination. In *Senebiera didyma* it may be observed that there are but two stamens; and they represent the taller pairs, one for each pair respectively. This reduction is a condition not infrequent in inconspicuous self-fertilizing flowers; for the number of stamens is often reduced, as mentioned above, in the flowers of several of the *Alsineæ* which do not require insect agency.

X. Note B.—On *Adoxa moschatellina*.

It may be interesting to some to have recorded the varieties which are found in the symmetry of the terminal as compared with the lateral blossoms. Of 71 heads of blossoms examined, all of which had the apical flower composed of whorls of fours,

60 had all four flowers 5-merous below,
3 had two 4-merous and two 5-merous below,
2 had three 5-merous and one 6-merous below,
3 had three 5-merous and one 4-merous,
1 had four 4-merous,
1 had two 6-merous and two 5-merous,
1 had the apical flower 5-merous, with three 6-merous and one 5-merous below.

This plant is also remarkable for the order of expansion in the different parts.

The terminal flower opens first; and its parts expand *all at once*. Of the lower flowers the two upper sepals of a flower open out first; then the two upper stamens are mature, and shed their pollen; next, the anthers below them dehisce in succession downwards, during which period the lower sepals begin to expand.

XI. Note C.—On the Origin of the Ternary and Quinary Symmetry of Flowers with indefinite and spirally arranged Members.

Calycanthaceæ.—Of the two genera comprising this order, both of which have opposite leaves, *Calycanthus* illustrates an abrupt change from opposite leaves to the $\frac{8}{21}$

arrangement in the bracts or bract-like sepals of the flower, but no differentiation occurs between the bracts, sepals, and petals respectively; whereas *Chimonanthus* (see fig. p. 191, in Le M. & D.) would seem to be a more highly differentiated type, in that not only is the calyx now distinguishable from the corolla, but five anterior stamens constitute a distinct whorl by themselves, and the indefinite barren ones of *Calycanthus* are here represented by five also.

How whorls or cycles of fives arise directly out of opposite parts has been fully described in my previous paper, quoted above, p. 181; so that I need not dwell upon it now.

Magnoliaceæ, *Berberidaceæ*, *Anonaceæ*, and *Menispermaceæ* are orders characterized by a ternary arrangement in their flowers, and by the whorls being usually double.

The origin of this might at first sight be thought to be the same as of the ternary arrangement, which is almost universal in petaloid Monocotyledons—namely, to have arisen from the tristichous phyllotaxis. But the fact that the perianth consists of 6 parts (=3+3) in the latter, and twice or more than double that number in some of the former, is significant, and would seem to imply a different origin, which I believe to be as follows:—For any phyllotactical arrangement corresponding to the fractions of the usual series, excepting $\frac{1}{2}$ or distichous, *every projected circle contains three leaves*; and on arresting the internodes of the flowers there always follows the tendency to alternation in position with the parts of the whorls immediately above and below. Hence the "threes" of each circle arrange themselves in a decussating manner. Thus in *Berberis vulgaris* we have 3 bracts, 6 (=3+3) sepals, 6 (=3+3) petals, 6 (=3+3) stamens, making in all 21 parts, corresponding to a cycle of the series $\frac{8}{21}$.

On the other hand, a flower of *Aconitum*, according to Braun, as quoted in Sachs's Text-Book, p. 530, is composed as follows: the sepals are pentastichous, or $\frac{2}{5}$; the corolla octastichous, or $\frac{3}{8}$; the stamens $\frac{8}{21}$, and the carpels 3.

Hence it would seem that there can be be at least four methods of disposing the floral members when numerous and spirally arranged, viz.:—

1. Spirally and with no breaks, then mostly $\frac{8}{21}$, e. g. *Magnolia*.
2. Broken up into fives, or $\frac{2}{5}$ arrangement . . „ *Chimonanthus*.
3. Broken up into threes, decussating . . . „ *Berberis*.
4. Broken up into whorls of 5, 8, 21, and 3 . . „ *Aconitum*.

XII. Note D.—On the Nature of the Corolla of *Primula*.

With regard to the theory of Pfeffer (see Sachs's Text-Book, p. 531), that in the *Primulaceæ* the corolla is an outgrowth of the andrœcium, I think there is more than one argument against it. Not only would the whole of the *Myrsineæ* have to be interpreted in a similar manner, but all analogy seems opposed to it. That the stamens are opposite the petals is true; but then *Samolus*, with its staminodia alternating with the petals, throws light upon this peculiarity; and if we examine the fibro-vascular bundles, it will be seen that ten pass into the tube of the corolla, five larger ones up the middle of each lobe, and *five smaller ones are intermediate*; each of the larger sends off a *small* bundle to the stamen adherent to the petal, respectively. The main portion

of the bundle continues its way to the notch at the summit of the lobe, and branches within the lobe. Now this is identically the same as in the calyx of *Prunus*, in which, as in the corolla of *Primula*, there are five median bundles, which do not bifurcate until they arrive at the lobes. The five bundles alternating with the petal-lobes of *Primula* or calycine lobes of *Prunus* bifurcate also on arriving at the notch between the lobes. They then send off dichotomously branching members up the adjacent edges of two lobes—that is, of two different members of the whorl.

The conclusion I would draw is this—that the calyx-tube of *Prunus* is homologous with the petioles, the lobes with the blades, and that the same holds good for the corolla of *Primula*; and I think we are justified in concluding that the corolla of the latter is a veritable foliaceous whorl.

Moreover the æstivation of the corolla of Primrose is strictly the same as in many other plants, and, if analogy is to be trusted, confirms this belief. Lastly, what is of chief importance is, that the theory being based, as no doubt is the only sound method, on development, is, however, as I interpret the facts, based on a misunderstanding of them—namely, that *because* the stamens appear first, and the lobes of the corolla *subsequently* (but they arise as soon as the anther is developed, *and are all connected by a horizontal band*), *therefore* the latter is an outgrowth of the andrœcium. But, as has been already observed, invariably acropetal or centripetal development of the whorls of flowers does not occur. That the corolla-lobes should develop *after* the stamens is by no means without parallel; for it occurs in many plants, as in the few following examples, in which the whorls are written in order of development:—

Ranunculus acris: Cal., St., Pi., Cor.
Stellaria holostea: Cal., St. opp. pet., St. opp. sep., Pi., Cor.
Lychnis dioica: same order, but without Pi.
Veronica chamædrys: Cal., St., Pi., Cor.
Cerastium glomeratum (self-fertilizing): Cal., Pi., St. opp. sep., St. opp. pet., Cor.
Arenaria trinervis (do.): same order.

XII. *On some Points in the Histology of certain Species of Corallinaceæ.* *By* Major-General R. J. Nelson, *R.E., and* Prof. Duncan (*M.B. Lond.*), *F.R.S., Pres. Geol. Soc.* *Communicated by* Dr. Murie, *F.L.S.*

(Plates XXVI., XXVII.)

Read June 15th, 1876.

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I. *Notice of the Histology of the Corallineæ by Quekett and Decaisne.*

Prof. John Quekett, who lectured at the Royal College of Surgeons, London, in 1850–1852, on the skeleton of invertebrate animals, published his course under the title 'Lectures on Histology,' in 1854. In the second volume that distinguished microscopist, whilst considering the calcareous skeleton of the Cœlenterata, very properly distinguished it from the remarkable hard substance of the Lithophytes, or the plants commonly known as Corallines. He gave a description of the common *Corallina officinalis* of the British coasts and also some important notices of the microscopical anatomy of the group. After noticing that when the Corallines are acted upon by dilute hydrochloric acid and the coating of lime is removed they become as flexible as any plant, he proceeded to explain that the terminal branches, which are of a round figure, exhibit the organs of fructification. The other species, *Corallina monile* and *Corallina opuntia*, he explained, are both largely coated with lime, but their joints are more evident than those of the common species. He then, after remarking upon the relation of the Nullipores to the Corallines, suggested that the comparison of the skeletons of the plants and of those of the true zoophytic corals is most interesting physiologically; for in both instances abundance of calcareous material has been separated from the sea-water by a vital process. He stated that on making a vertical section of *Corallina officinalis* "we shall find that on examination with the lowest powers it will exhibit two kinds of structures, both of which are essentially cellular—that on the exterior being formed of small cells of hexagonal figure, whilst on the interior they are more elongated and generally of a brownish colour: this is especially the case if the section should include a joint. In the fresh state the contents of the cells can be easily made out, and the central ones are not

unfrequently full of greenish granules like chlorophyll. The lime is not in the interior of the cells, but appears to be on the outside of the cell-walls, which are rendered opaque and thick in consequence." He examined this section with a power of 200 diameters, and delineated the results *. The drawing shows a very irregular patchwork of white spaces amidst a dark matrix; and the spaces represent the irregular cells without lime surrounded by the calcareous intercellular mass. Some long fibres are shown to be part of the articulation; and they are destitute of the mineral. He illustrated the general anatomy of the plant further by making a transverse section of a joint (*i. e.* a part between two articulations), and by dissolving it partly in dilute hydrochloric acid. The drawings † given by him exhibit the outer part of the section decalcified, and the inner as still retaining some carbonate of lime—so that externally there is a broad series of more or less hexagonal cells in radiating rows, whilst internally the cut extremities of the smaller cells are seen to be surrounded by opaque mineral matter. There is a remarkable addition to this delineation, which is not referred to in the context, in the form of a space included between two lines, which represents a homogeneous tissue on the surface of the lithophyte.

In noticing *Corallina incrassata*, he explained the very flexible nature of the articulations—and that by making a vertical section of one the elongated cells of it could be distinguished without any lime upon them, and having often a green colour. The delineation given of these sections shows long internal and hexagonal external cells, with a perfectly plain margin to the free surface of the plant.

Finally, in noticing the absence of any such articulation-cells in the Nullipores, he accounted for it by their slow growth in comparison with the more rapid increase of the Corallines, whose calcareous covering was therefore all the less.

It will be found on comparing Quekett's histological work with the essay by M. L. Decaisne ‡, that he was so far in advance of that author that it is hardly necessary to allude to it here. But there are some points of interest in M. Decaisne's paper, and some others which, if not explained, might appear to have forestalled the present communication.

The illustrations given by M. Decaisne are in plate 17 of the 2nd series of the Annales des Sciences Naturelles, 1842, vol. xvii. (the plate is marked "tom. 16"); and nearly all have been much improved upon by Quekett.

But the illustration of *Cymopolia barbata* is remarkable. The figure (12), of the natural size of the plant, resembles the appearance of the structures of many Corallines when magnified. Fig. 12 *a*, however, explains that the endings of the frond are dichotomous branchlets, which are covered with carbonate of lime. They thus differ from what will be explained further on. M. Decaisne noticed (see fig. 14 *a*) that a mucilage covered the *Corallina opuntia* (*Halymenia opuntia*), and that it formed a sort of cuticle which covered the surface of the articulations; but his diagram of the network of cells formed by the contact of those of the superficies is not in advance of that of Quekett.

* John Quekett, Lectures on Histology, 1854, vol. ii. p. 169 *et seq.*, fig. 85, p. 171.

† Quekett, *op. cit.* vol. ii. p. 171, fig. 85, fig. *d*, and fig. 86.

‡ L. Decaisne, Ann. des Sci. Nat. 2nd ser. vol. xvii. plate 17. Classification of Algæ.

II. *Notice of M. Rosanoff's Essay on the Histology of the* Melobesiæ, *so far as it concerns this communication.*

In 1866 Rosanoff contributed a paper to the Société des Sciences Naturelles de Cherbourg (2e sér. tome xii. pp. 1–112, plates i.–vii.) on the *Melobesiæ*; and, apparently ignorant of Quekett's work, he proved that anatomist to be correct, and advanced much beyond him. As we do not include the reproduction of those lithophytes in this communication, it will only be necessary to notice what M. Rosanoff states regarding the vegetative growth, so far as it relates to the Corallines. He considers that the carbonate of lime is in the intercellular spaces, or between the longitudinal walls of the cells, in the cell-walls, and in the position of the primordial utricle, and that it is arranged molecularly in the cellulose of the cell-wall. He does not find it in a crystalline or granular form, but as a thick and more or less perfect layer. He notices the variable amount of the carbonate of lime in different species. On examining the cell-walls of *Melobesiæ* he found them (before decalcifying) punctate or granular; and this structure resembled parallel lines crossing each other at almost right angles: hence he considers the lime to be intimately associated with the cell-wall structure. He observes that the reproductive parts are deficient in carbonate of lime; but he does not find that the rapidly growing portions of the plants are so deficient in it as might be expected; nevertheless he asserts that the parts deficient in the mineral are the free surfaces of the terminal cells.

M. Rosanoff shows that the cells of the plant are furnished with pores, one on each side of the cell-wall, perpendicular to the direction of growth, and that the pigment, starch, and protoplasm of the cells accumulate in their upper and outer parts. He explains that although each series of cells is radial, and grows by increase of the periphery, there is an increase laterally, and which relates to the shape of the frond. This takes place by what he calls copulation of cells, and is influenced by the pores in contiguous cell-walls. The copulation appears to be an absorption of the cell-walls of contiguous cells and a resultant irregular and large cell; and the pores permit of the nutrition of the deeper cells, so as to contribute an amount of common nourishment. He describes some large cells termed heterocysts.

M. Rosanoff explains that the *Melobesiæ* have a glutinous feel when touched on their surface; and in his diagrammatic sketches he places isolated cells on the free surface, each being the termination of a series leading deeply down *.

The Corallinaceæ have been the subject of our independent investigation; and most of the work of one of us (Major-General R. J. Nelson, R.E., then Lieut. Nelson, R.E.) was done in the Bermudas many years since. The drawings from life were then taken. Subsequently one of us working on the subject of the physiology of the Lithophytes, and unknown to the other, had examined the British and some other Corallines with care. Hence this joint memoir.

* Other writers (who do not offer any thing new) on the histology of the vegetative structures are Harvey (Brit. Marine Alg. pl. 13 C; Phys. Brit. pl. 222), Decaisne (Ann. des Sci. Nat. 2e sér. xvii. pl. 17. fig. 1, xviii. p. 119; The Micrographic Dictionary, 3rd edit.). See also Lamouroux, Bull. Soc. Phil. 1812 and 1816, p. 313; Philippi, in Wiegm. Arch. 1837; Kützing, Phyc. Gen. and Spec. Alg.

III. *On the Bermuda Corallinaceæ; their simple and compound filamentous epiderm; the structure of the external cellular tissue of the frond, its relation to the deposit of carbonate of lime, and the nature of the internal tissue.*

The high temperature of the sea at Bermuda, the absence of a cold season, and the abundance of carbonate of lime in and about its reefs, favour the growth of the Corallines and Nullipores. Under these physical conditions these plants assume an appearance of great beauty; for in the still pools amongst the reefs they may be seen in luxuriant profusion, each frond being enveloped in a delicate halo of filiform vegetation. Instead of the white or purplish smooth exterior which is so familiar to the investigator of northern forms and of dead specimens, that of the living Bermuda Corallines is hirsute, the hard calcareous analogue of the less-favoured species of Europe being beset with vigorous cell-growth. (Plate XXVI. figs. 2, 11, 14, 15; Plate XXVII. figs. 11, 13.)

In the warm sea of the Bermudas white Corallines are rare, and the prevailing colour is green, as in *Corallina tuna*, or full bright grass-green, as in *Corallina tridens*; sometimes the tint is bluish-green; and some Corallines are brownish green or even plum-coloured.

Their filamentous vegetation, or cell-growth, varies in amount and in its details according to the species; but in every instance it is continuous with the outer cells of the mass of the frond. The filaments are wonderfully varied in form * and structure: sometimes they are merely tubular and unicellular; sometimes they are very distinctly articulate; and in some species they branch. Their length varies also; for whilst in some vigorous forms they exceed in length the diameter of the joint of the frond to which they are attached, in others they are not quite as long, and in certain species they are not more than $\frac{1}{10}$ or $\frac{1}{20}$ of the length of the diameter of the plant. Many contain extremely minute spherules of chlorophyll or, rather, of colouring matter, whose minute bodies have such a significant appearance that they suggest some other physiological bearing than that of simple colouring matter. (Plate XXVI. figs, 3, 12, 16.)

These filaments, radiating on all sides and crowded together, resembling a confervoid growth on the frond, do not appear to be contractile; for they are passive under the movements of the numerous minute animals which move up and down and in and out amongst them. They possibly form the food of many minute animals, and are thus liable to be removed from their parent frond, a process which washing and drying will imitate. Nevertheless, if the algæ are carefully collected and placed on paper, traces of the filaments will last for a long time.

Very long filaments which are single, and have a direction rather oblique to the frond, are seen in *Corallina vermicula*. Filaments which are crowded and short, and which bifurcate, exist in *Corallina tridens*; and still shorter ones are observed with bifurcate and club-shaped ends in *Corallina tuna*.

Under a magnifying power of 100 diameters the outside of the dried frond of *Coral-*

* In order to see them to perfection the plant must never leave the water, and should be put into a glass vessel under the surface, and then removed in its temporary aquarium.

lina vermicula is covered with very regular and small polygonal spaces. Each space is separated by a narrow raised border from its neighbours; and the surface within the border is more or less depressed and has a central opening. The border and depressed surfaces are of carbonate of lime; and the first represents the junction of the outer cells of the cellular tissue of the frond at the outside, and each of the depressed surfaces consists of the carbonate of lime in the cell-wall of a collapsed superficial cell. Where there was no carbonate of lime in the central spot there was perfect cell-wall; and this disappears during desiccation. But the filament, long and slightly oblique, arose from this central spot, and therefore was much narrower than the whole cell from which it sprang, and was continuous. (Plate XXVI. fig. 17.)

In some parts of a specimen the minute dot-like space uncovered by carbonate of lime is not central, but close to the edge of the polygonal area; so that the filament did not arise invariably centrally, but often at one end; and it appears to be oblique. The polygonal spaces moreover differ in size, and some are more elongate than others; so that the distribution of the filamentous growth is not perfectly uniform. Towards the end of the frond the calcareous element does not predominate as it does elsewhere; and the green tint of the cells which are not affected by the mineral is very distinct.

On decalcifying specimens it is observed that the calcareous matter is granular, and that it is between the cells, in the cell-wall, and also within the cell to a certain extent. The inside of the frond is eminently cellular, and consists of series of long tubes and of compressed globes of carbonate of lime with faint central hollows placed longitudinally and radially. Beyond them is the outer coating of polygonal cells, which are intruded on by carbonate of lime—on their sides perfectly, but on their distal and proximal ends imperfectly, so as to leave some cell-wall in those situations. (Plate XXVI. figs. 15–17.)

Corallina tridens, when dry, has its surface covered with minute pits separated by ridges so as to assume a polygonal shape; and at the bottom of them, even in very old specimens, a dry slender filament may be seen projecting from a central part where there is no carbonate of lime. The spaces between the projecting ridges (or the pits) are produced by the collapse of the cell-contents during drying, and form part of the free ends of the external layer of cells. Each cell corresponding to a pit was infiltrated with carbonate of lime (except a minute central spot) during life. A very delicate cell-membrane covered the pits and ridges, and was continuous with the filaments also; this will be noticed further on as the analogue of the superficial epidermic layer of the British Corallines. Relics of this membrane are seen in dried specimens. It contained green colouring matter: and where it has been abraded the carbonate of lime of the underlying cells is glistening and white.

The filiform processes are very numerous in the living specimens, and form a complete down on the surface. They arise by a kind of neck-like constriction from the most external cells (those of the pits) of the frond, and are wider at their distal end, being otherwise cylindrical. They give origin at their remote end to two neck-like processes, which subdivide rapidly, and end in long club-shaped cells; so that the original filament produces four others. They are all tense with fluid and with marked distinct and numerous globular granules, more or less tinted green. (Plate XXVI. figs. 10–13.)

Corallina tuna, a bright green succulent Coralline, resembling *Corallina opuntia* in its habit, has its broad joints covered with a down of crowded and articulated filaments. The filaments are of several kinds. Some are simple long club-shaped cells; others are of the same shape at their base, but become compound by giving forth cells from the free end; and many, after having had these secondary cells developed, have others growing from them. All the cells are narrow at their origin, cylindrical, and largest at the end. (Plate XXVI. figs. 1–3.)

The surface of the joints of the frond is covered with a very minute areolation. Each minute area has its limiting ridges, and is regularly hexagonal, the ridge between the areas having a fine line on it. Each area is the top of a cell; and the ridge represents the intercellular space and the cell-walls also: it is calcareous. The calcareous deposit does not transgress over the front of the outside cells (those forming the areas) as it does in the Corallines already mentioned; so that almost all the area is semitransparent in dried specimens. But there is a little calcification of the outer wall nevertheless, except near the centre whence the filiform appendage of the cell arises; for the wall has a vitreous appearance. (Plate XXVI. figs. 4–6.)

The green colour of some of the dried joints is partly due to the preservation of an external superficial cell-membrane which covered all the calcareous cells, and which, as in the other Corallines, is a kind of lateral expansion of the base of the filiform processes, and is seen in *Corallina tridens* (see page 201). In the dried specimens the processes may be just traced, their proximal ends lying in the hollow of the area. The hollowing of the area depends upon collapse of the cell during desiccation.

This Coralline is only calcareous externally; for within there are ramose masses of great elongated simple cells, forming trunks near the articulation, and very fine branchlets near the underside of the outer expansion of the joints of the frond. Hence, on removing the film of calcareous cell-matter which forms the outside of the joint, these ramifications become visible. (Plate XXVI. figs. 1, 2, 9.)

On decalcifying a dry specimen, the paucity of the carbonate of lime in the frond becomes evident; for the ridges between the polygonal external cells are then seen to be mainly composed of true cell-wall: hence the mineral is mainly within that structure, and not much between the cells. There has been a deposition within the cells; for the relics of the cytioplasm are seen in some crowded up in a mass. The cells themselves look crumpled more or less, so as to give the appearance of raphides within them.

On the edge of a frond, in a decalcified specimen, the bases of the filiform processes could be seen, and a perfect process also. The cell-wall of the processes is well developed, and has glandular markings and slight prominences on it. (Plate XXVI. fig. 8.)

The ramose cellular structure within the joints is very remarkable; some of it consists of huge long cells constricted here and there, and of smaller cells with neck-shaped processes terminating in round bottle-shaped ends, which underlie the external layer of polygonal cells. (Plate XXVI. fig. 9.)

These species may be taken as the types which explain the external construction of the Corallines, and, to a certain extent, their internal configuration. They are all rapid

growers in comparison with the species of temperate seas; and they contain less carbonate of lime, joint for joint, than the well-known Corallines of our seas, although the whole plant may contain much more. Their cells are larger, and the whole plants present in their minute anatomy a great resemblance to some other little-known Bermudan Algæ, but which, whilst they resemble filamentous Rhodosperms, include carbonate of lime within their cellular tissue. The function of the filamentous processes and of the external delicate membrane can be readily interpreted. They are the only means by which absorption of the sea-water, and therefore of nutriment and carbonate of lime can take place. When once the intercellular spaces and the cell-walls have become infiltrated with granular carbonate of lime, no further nutrition can proceed. At this time the deposit is free to collect within the cells; for the cytioplasm contains it. When large cells are cut into, they emit a rice-water-looking liquid, which deposits granular carbonate of lime.

The fronds increase, as it were, exogenously, by division of the external cells of the layer which gives origin to the filamentous processes. The superficial epidermal layer also develops a succession of external coatings to the frond; and therefore several of the above-mentioned layers are derived from it. The arrest of growth and the deposition of carbonate of lime have evidently some common relation. Hence in all probability the introduction of the mineral in the soluble form of the bicarbonate into the cytioplasm, cell-wall, and intercellular space progresses during the early life of the frond and whilst growth is proceeding. But as starch, cellulose, and carbonaceous granules accumulate, as growth becomes less vigorous a part of the carbonic acid of the bicarbonate is decomposed, part is retained, and part is lost, and the insoluble carbonate of lime is precipitated in the granular form.

The merging of one cell into another (the "copulation" of Rosanoff) has not been observed in the Bermuda Corallines; nor has any thing like a regular porosity of the cell-walls. But the presence of round spots where the cell-membrane is thin and more pervious to light is occasionally to be noticed in decalcified specimens.

In the cell-wall of the long internal cells there are markings which indicate a difference in the thickness of the wall; and on the surface of the frond the delicate external epidermal layer may be distinguished by curious puckerings and markings in its delicate tissue.

IV. *The Histology of the Epiderm of the Frond of* Corallina officinalis *from temperate seas; notice of the Structure of the Cells of the Mass of the Frond.*

The common British *Corallina officinalis* should be studied in the early spring time; for then its origin, from a greater or less expansion, may be examined, and there is then not much carbonate of lime in the frond. The expansion and short stumpy fronds are of a beautiful claret or port-wine-and-water colour, the articulations and the tops of the joints being greenish or colourless. Care should be taken to remove the stone to which the plant is attached without any washing movement; or the delicate external layer will be destroyed. The microscopic specimens, sections, &c. had better be mounted in glycerine; and if any acid be used, it should be weak hydrochloric

acid, the glycerine being used after washing as the medium. A polarizing apparatus is necessary. (Plate XXVII. figs. 1–9.)

Let the acid solution act slowly and for some time if the internal structures are to be examined; but if the delicate film of tissue which covers the frond is to be shown, a rapid development of gas-bubbles is rather an advantage; for it is tolerably certain to happen that some bubbles escape and blow out this tissue so that it can be examined.

Young specimens should be obtained; for experience and observation prove that minute Gasteropoda browse over the Corallines, and destroy much of the superficial cell-growth before it is much infiltrated with the carbonate of lime.

The surface of the frond of the Coralline, and also of the little basal expansion from which it rises, is covered with an exceedingly delicate cell-membrane (Plate XXVII. fig. 3). This is usually demonstrable after the action of dilute hydrochloric acid upon the frond; for the bubbles of gas escaping, separate it from the cellular mass of the plant which it covers. It resembles a beautiful pavement epithelium; its broad and shallow polygonal cells usually, but not always, touch by thin walls, and the whole is colourless. When seen in section in semi-decalcified specimens, the cells are observed to overlap those below, and, whilst covering the intercellular space, to be in organic connexion with the distal ends of the cells of the mass. No calcareous element enters into the composition of this superficial structure. Here and there an additional cell is seen on the free surface and covering one of those polygonal in shape; and near the joints, in some rare instances, the polygonal cell gives rise to a thread-like cell of about the length of $\frac{1}{4}$ of the breadth of the joint (Plate XXVII. fig. 2). In some forms from Port Natal, which greatly resemble *Corallina monile*, Ellis, the surface-membrane extends from joint to joint, covering the articulation and its elongate cells. This external tissue gives no evidence of containing carbonate of lime; but the cells have minute refractive dots in them. Finally, it is thickest at the free end of the joints of the frond, and there often exhibits rather tall cells, united together by a structureless protoplasm.

Beneath this superficial tissue are the terminal cells of the mass of the frond; and they are continuous with long rows more deeply seated. Each of these terminal cells is of a light green, and it succeeds a series which, gradually becoming darker with depth, assume a port-wine colour. The cell-wall is stout, a portion of it being perfectly transparent even in old specimens. This transparent portion forms either part or the whole of the distal end of the cell; and nearly all the rest is opaque. On decalcifying, it is found that the cell-wall, especially at the sides of the cell, and not at the ends, is incomplete here and there, as was noticed in the *Melobesiæ* by Rosanoff. There appears to be a possibility of connexion between the sides of contiguous cells. That this is a normal condition is probable from the small number of the pores; for did the incomplete condition depend on the removal of raphidic masses of carbonate of lime, there would be more of the pore-like markings, and their position would be irregular *.

* A careful examination proves that some markings on the longitudinal sides of the cell-walls of Corallines, already noticed, from Bermuda, are spots of excessively thin cell-wall. They are circular in outline, very few in number, and transmit light more readily than the rest of the tissue; they are, then, not absolute pores, but are pore-like, and are the seat of a very thin and diaphanous membrane.

The terminal cells contain viscid protoplasm, dark granules, and a nucleus. Their sides are, after decalcifying, evidently in contact; and when the process has been only partially carried out, a granular mass of carbonate of lime is seen to hide the side walls of contiguous cells, and to intrude on their internal space.

Having their side walls in contact after decalcifying, it is not probable that there can have been much of the calcareous element between the cells; there was some in the cell-walls, and also in the position of the primordial utricle. There is, however, frequently a small amount of calcareous deposition in the distal end of these outer green cells, but not enough to cover the whole surface. Nevertheless, when the whole frond of *Corallina officinalis* has matured, the whole of the distal end is covered, and thus the organic connexion between the superficial tissue and that beneath is destroyed. The proximal end of the outer green cells is in close contact with the upper wall of the cells beneath; and in the early days of the growth of the frond there is very little mineral deposition there: but later it occurs, so that finally these cells, and the others beneath them in the mass of the frond, are quite surrounded by opaque carbonate of lime, which is, moreover, amongst their cell-walls and within to a certain extent.

The superficial epithelial-looking layer of the British Corallines, and of some from Port Natal, is the homologue of the delicate homogeneous layer covering the more rapidly growing and less calcareous Corallines of the Bermudas; and the flat cells of the one are the analogues of the long slender filamentous processes of the others.

In some decalcified specimens from Bermuda the cell-wall of the cells supporting the processes, and of the deeper cells also, is very thick, and no pores are to be seen. After much, but not all, of the carbonate of lime has been removed, it is seen to be granular, to be included in the substance of the walls, between them, and in the cell. And when this last state occurs all the solid contents are crowded up in the middle. In a young frond of *Corallina officinalis* these outer cells are seen to be dotted on their sides with minute dark punctations after the action of acid.

Beneath the outermost green-coloured layer of cells of *Corallina officinalis* are others of the same colour or else of a light port-wine tint. They have dark granules, some of considerable size, within them; and in the instance of the port-wine-coloured cells the colouring matter is in solution as well as in the granules. The cells are cubical or oval in outline, some being elongate; they are in close contact with those in front and behind; but an intercellular space exists around the sides. That is to say, after decalcification, the slightest pressure will separate the sides of groups of cells; and it is in this position that the bulk of the calcareous element is deposited. This imperfect adhesion of the sides and the decided organic connexion between the ends of the cells in linear series, is more or less seen throughout the frond.

In young fronds the cells, especially when they are elongate, are crammed with cytioplasm, which aggregates in separate masses so as to exhibit a small moniliform series; and in the midst is a rather large nucleus and nucleolus. Sometimes there is to be observed a large circular dark line encircling a small zone of diaphanous wall, in the midst of which is a circular dark spot. All these cells are distinctly tinted. (Plate XXVII. fig. 7.)

Deeper still in the frond the linear series of cells, which are placed radially, are seen to branch; or, rather, two or three series unite deeply in one, and the size of the inner cells increases. All are very distinctly separate by their sides after the action of acid.

Amongst these deeply seated cells there are some which are long and fusiform; they run longitudinally through the joint, and deeply. They are observable in the middle joints, and not in the younger and terminal ones of the young frond. Each is crammed with two or more linear series of slightly flattened spheroids of colourless matter, very amyloid in appearance. And whilst in some a mass of dark port-wine-coloured cytioplasm may exist at one end, and a series of the amyloid bodies at the other, the majority of these cells, which sometimes bifurcate, are colourless; and in many no cell-wall can be distinguished, on account of the close packing of the contents. (Plate XXVII. fig. 9.)

These long cells, with their remarkable contents, are in relation with the filiform cellular processes of the articulations, and are often distinctly continuous with them, especially with the deeply seated ones, which run in a longitudinal direction throughout.

Each articulation consists primarily of a mass of long cells placed between the joints, and it has a deep and a superficial part.

The superficial part of the articulation consists of a thin layer of epithelium-looking cells, well seen by polarized light, and which is continuous with the common superficial layer of the frond; then follow long cells crowded closely together, and having a faint green tinge. Each cell has a thick wall, which is more transparent than the elongate protoplasmic contents; and usually the cell is long enough to extend from one joint to the other. It then is fixed on to a broader and shorter cell, whose direction is oblique and more or less radial; and it contains more or less colouring-matter, green or dark red. This obliquity of the outer layer of the articular cells close to the joint produces decomposition of the polarizing ray, and the phenomena of alternating light and darkness and of complementary colours.

The deeper cells of the articulation are elongate, like the others; they are very long, numerous and crowded, and have thick cell-walls and a linear mass of cytioplasm. They pass straight on in either joint, and merge into long cells without colouring-matter, or else into a series of the fusiform cells noticed above.

It appears, from examining very young specimens, that the outer part of the articulation is developed from the outer layers of the joints by elongation of their cells, and that the deeper layers are produced from the elongate and longitudiual series of the frond.

As growth proceeds, the fine tissue on the articulation is lost, the long cells increase in breadth and length and in the thickness of their walls, their contents becoming semi-solid.

Occasional dissepiments occur in the long cells of the articulation, and also short processes of the cell-wall; but often they are not visible. Polarized light, however, is a great assistant in the investigation.

A small amount of carbonate of lime is found amongst the superficial layer of cells; but it does not appear to exist in and amongst the deep and long cells of the articulation.

In older fronds, and in some Corallines from Port Natal, the superficial epidermic layer is very distinct; and beneath it the cells of the first layer of the mass of the frond

are convex outwards, having very thick walls; but their walls are not usually perfect in outline. They have a double contour-line; and this ceases over a greater or less part of the position where cell-wall might be expected to be found. This absence is due principally to collapse of the cells after decalcification, and, to a certain extent, to the presence of a lateral pore. (Plate XXVII. fig. 5.)

The absorption of the adjoining cell-walls of cells and the conjugation noticed by Rosanoff have not been observed in the sense in which the terms are employed by that author. In the mass of the frond a large cell may be seen to have incomplete dissepiments at its distal end; but these are the beginnings of the sprouting of two perfect cells from it in order to multiply the series. This occurs largely all over the joints, and even in the outer layer, the increase being lateral there and in the direction of the periphery.

V. *The filamentous Processes of the* Melobesiæ *of the Bermudas.*

Like the Corallines, the *Melobesiæ* live and flourish luxuriantly in the Bermudas; and it is interesting to announce that, like their articulated allies, they present external appearances of which no conception has been had by the observers in temperate climates*.

The Nullipores chosen as the types upon which to explain the appearance of luxuriant external filamentation, and which form the subject for our plates, are two in number:—First, a very ramose species, with rather expanded ends to short and widely diverging branchlets. (Plate XXVII. figs. 10, 11.)

The branchlets are solid, very concentric in their layers, and are minutely punctate.

The fine hair-like growth from their external surface is wonderfully developed; and the extremely delicate and greatly crowded filaments are as long as the branch is broad. They radiate in all directions.

The second form arises from a stem; and its branches, irregular in shape, inosculate, and ascend close together, so as to form a conical mass. (Plate XXVII. figs. 12, 13.)

The crowded filamentous growth is placed around the branches, and extends outwardly from the frond to about one half of the diameter of the branch.

It is evident that these filamentous growths are the analogues of those of the Corallines, and that all have the same important function in the nutrition of the plants.

* Nullipores are closely allied to the Corallines both in structure and in their office in nature. Any one who has studied the blocks and masses of coral reef which the Sapper and Miner has blown up when they impede navigation, —or *on* which the naturalist has crawled, or *round* which he has been wading or swimming by the hour together—will readily admit the good service done, not only by *Nullipora*, but by many and many another firm and respectable *Vegetable Coral* as a cement, cooperatively with the bond, at times, supplied by Gorgonidæ &c. in the formation of so-called Coral Reefs, in a way quite distinct from the comparatively homogeneous proceedings in the structure of Tubicola reefs.—R. J. N.

DESCRIPTION OF THE PLATES.

Plate XXVI.

Fig. 1. *Corallina tuna*: natural size.

Fig. 2. A joint magnified, and showing the hirsute surface and the long branching internal cells.

Fig. 3. Filiform processes or hairs from the outside of *Corallina tuna*, magnified.

Fig. 4. A portion of the surface of an old and dry specimen of *Corallina tuna*, magnified, showing the spots in the cells where there is no carbonate of lime.

Fig. 5. An external cell of the same Coralline, more highly magnified. The dark spot is the position of the former attachment of a hair or filament.

Fig. 6. An external cell collapsed and the relics of a dried filament, magnified.

Fig. 7. External cells of the frond of *Corallina tuna* decalcified, and magnified.

Fig. 8. Part of the edge of a decalcified frond of *Corallina tuna*, showing the hairs and glandular markings on them, magnified.

Fig. 9. The large simple and branching cells of the interior of the frond which terminate at the base of external cells, magnified.

Fig. 10. A portion of the dried fronds of *Corallina tridens*.

Fig. 11. A portion of a fresh frond, magnified, showing the superficial hirsute covering of filamentous growth.

Fig. 12. A group of hairs arising from the external cells of the frond of the same Coralline, magnified, from a fresh specimen.

Fig. 13. The appearance of the external layer of cells, with vestiges of dried filaments and of parts without carbonate of lime, magnified, from a dry specimen.

Fig. 14. A group of *Corallina vermicula*, after Nelson and from the living specimen.

Fig. 15. A fresh frond, magnified, from the life, showing the oblique and long hairs, of *Corallina vermicula*.

Fig. 16. A group of external cells and their long hairs, from a fresh specimen, magnified.

Fig. 17. External cells of *Corallina vermicula* with broken cell-wall, indicating rupture of the filaments. From a dry specimen, magnified.

Figs. 2, 3, 11, 12, 14, 15, 16, are from drawings from nature by Major-General Nelson, R.E.; figs. 1 and 10 are from specimens collected by Major-General Nelson.

Figs. 4, 5, 6, 7, 8, 9, 13, 17, are drawn from specimens prepared by Prof. Duncan, and under his direction.

Plate XXVII.

Fig. 1. A portion of a young frond of *Corallina officinalis*, magnified.

Fig. 2. A portion of the same frond close to the edge of an articulation, showing scattered and long simple hairs, magnified.

Fig. 3. A portion of the surface of a frond decalcified. The lower arched portion has become separated from the upper and darker part by accident; it indicates the superficial layer of cells. Magnified.

Fig. 4. The superficial cell-layer, from above, magnified.

Fig. 5. The appearance presented by the outer cells of the frond beneath the layer above (figs. 3 and 4) in decalcified specimens. The thickness of the cell-wall and its incomplete condition are shown. Magnified.

C. Berjeau lith. CORALLINES & STRUCTURAL DETAILS. Hanhart imp.

C. Berjeau lith.

CORALLINES AND NULLIPORES.

Hanhart imp.

Fig. 6. Internal cells of a frond decalcified, showing pore-like markings, magnified.

Fig. 7. Internal cells, crowded with dark-red granules and spheres of the same tint, ending in elongate cells, forming part of the articulation, magnified.

Fig. 8. One of the broad cells, magnified, showing a collection of cytioplasm.

Fig. 9. A mass of refractive granules from one of the cells in a young frond, magnified.

Fig. 10. A portion of a ramose nullipore (*Melobesia*) from Bermuda, natural size.

Fig. 11. A litttle branch of the mass, magnified, showing the great development of the external filamentous growth.

Fig. 12. An undescribed species of *Melobesia*.

Fig. 13. A portion of the mass covered with the filamentous growth from the external cells, magnified.

Figs. 1—9 are drawn from specimens prepared by Prof. Duncan.

Figs. 10–13, are from drawings by Major-General Nelson.

XIII. *On the Minute Structure and Mode of Growth of* Ballia callitricha, *Ag.* (*sensu latiori*). *By* W. Archer, *F.R.S.*, *M.R.I.A.* *Communicated by* W. T. Thiselton Dyer, *M.A.*, *F.L.S.*

(Plates XXVIII. & XXIX.)

Read June 15th, 1876.

SOME small fragments only of this alga (mixed with some of the freshwater algæ enumerated by me in the Society's 'Journal,' No. 87) were at first met with in gatherings made by Mr. Moseley, of H.M.S. 'Challenger,' in Kerguelen's Land. They were much macerated and wholly deprived of colour, very few of the cells indicating the presence of contents, and the cellular structure being rendered hyaline. I submitted such a specimen to my friend Prof. E. Perceval Wright, who, aided by one at same time given to me by my friend Mr. Gilbert Sanders, identified it as a form of *Ballia callitricha*; and on comparing it with perfect examples in the herbarium of Trinity College, Dublin, the diagnosis was sustained. However, on a closer search of Mr. Moseley's collection, I afterwards found that it contained, in addition to the isolated and broken-up fragments, some complete and characteristic examples of our *Ballia*; so that the identification was complete. I was much pleased to find these latter in the gathering, as they afforded, of course, much more suitable subjects for study—though even the first small shreds which I had noticed not only presented examples of a minute and apparently characteristic structure within the cells, which thus seems to possess some histological interest, but they likewise showed some interesting points relating to the outward configuration and mode of growth of this alga, all of which, so far as I can see, seem to have hitherto remained unnoticed.

The fact that a Rhodosperm should have occurred in a collection made from fresh water and containing characteristic freshwater forms, possibly does not in reality possess that amount of interest which at first glance might seem to appertain to it. It is true that the algæ of marine type which strictly belong to the fresh waters are very few, and they are but of small dimensions and humble habit, and not at all striking. Such are, for instance, *Chantransia*, *Bangia*, *Hildenbrandtia*. In *Ballia* we have a type, indeed, more elevated, more pronounced, than any of these, an elegantly configurated and compoundly branched form; but I should be much inclined to suppose our specimen was a mere marine *waif* (possibly blown in by the wind); or it may have been taken from a site to which the sea had only occasional access (and cast in by the surf)*. The more

* I am further indebted to Prof. Perceval Wright for drawing my attention, however, to a record by Dr. Montagne (addressed to the Academy of Sciences, May 13, 1850) of the fact that M. Lemprieure had collected in the running waters of Guiana three species of *Bostrychia*, one *Gymnogongrus*, and two of *Ballia*. These were found either in rivulets of the mountains of Mahuri ("80 kilo." from Cayenne) or in the watercourse of the creek Gravier, in the Kan mountains ("40 kilo." from the sea, and at an elevation of 100–150 metres). The waters presented no trace of salt; and their elevation precluded all thought of any flow back of the tide bearing germs of these plants. Of the *Ballia* examples, which were minute forms, one (*Ballia pygmæa*, Mont.) grew attached to a *Batrachospermum*, the other (*B. lemprieurii*, Kütz.) to stones.

important interest of the specimen, then, attaches rather to its being the first in which the specialities alluded to have been noticed.

The whole plant is of a rigid and tough character; nor, when it is viewed under the microscope, is this surprising, when the cell-wall is seen to be so very thick, composed as it is of several laminæ. Now the peculiar and interesting internal character alluded to is, that in the boundary walls of the cells or "joints" there occur always two opposite terminal, and in some of them, in addition, two lateral, pairs of more or less wide (seemingly circular) pits—a character, indeed, found in other Rhodophyceæ, long ago pointed out by Nägeli*; but what would appear to be novel (so far as I know, indeed, it is unprecedented in other departments of plants †) is, that each of these pits is covered by a comparatively large *lid* or *stopper*, not organically united or persistently adherent; at least very small accidental force seems to suffice to dislocate and remove them.

In Mr. Moseley's example, in every joint of the plant, whether of the main stems or rachises or of the ultimate ramifications (except the apical joints), there occurs a "pit," with its "stopper," at *each end of each joint*—that is, at least two such in each cell (see the figures *passim*); in the apical joints there occurs but one (at the base). In many cells of the rachises and of certain lateral cells (presently to be noticed) there occur besides *yet other pairs of smaller pits and stoppers*, as will be hereafter explained. Why these pits

* 'Die neuern Algensysteme.'

† Something optically resembling the "stoppers" above referred to presents itself during the conjugated state of *Mesocarpus nummuloides*. It is well known that in *Mesocarpus* the spore is formed within the transverse canal (formed in the characteristic manner between the two conjugating cells) by the passage thereinto of their chlorophyll-plates enclosing the granular and oily contents, which become massed in the middle, whereupon ensues the division of the now H-shaped cell into three by formation of two septa, one to each side of the transverse canal, the middle cell becoming the spore, the two limbs (the parent cells) cut off seemingly as effete, though still containing colourless slightly granular plasma. As maturity advances, and when the spore presents its three consecutive walls, the median brownish and coarsely scrobiculate, it is seen to be ultimately freely suspended in the surrounding medium, but still posed between the somewhat geniculately bent pair of parent cells. Now, in addition to the original septum cutting off the primary parent cells, the outer apertures of the disjunct transverse canal, now separated at both sides from the free spore, is seen to be *covered by a plano-convex "lid,"* much thinned off at the periphery, of a semipellucid, somewhat "pearly," aspect, and sufficiently strongly calling to mind the appearance of the "stoppers" in *Ballia* above referred to. This lid in *Mesocarpus* may be seemingly composed of a condensed kind of mucus. What its purport, I could not hazard a conjecture; but it certainly appears puzzling that so much pains, as it were, should be expended on hermetically "sealing up" these apertures in a structure whose function would appear to be over, containing, indeed, some as yet living (?) plasma, though robbed of its chlorophyll, but nevertheless seemingly destined to be but cast off as of no further moment.

The "lids" here adverted to are often, indeed, sufficiently obvious; yet I do not know that they have been noticed in algal works. Their possessing a certain amount of *resemblance* to the stoppers in *Ballia* renders an allusion to them here possibly not altogether out of place, though in the case of *Ballia* the stoppers are within the cell-cavity, but external to the "primordial utricle," whilst in *Mesocarpus* the corresponding structures are (at least ultimately) external to the cell—that is, washed by the surrounding water: still their deposition must presumably have been carried on, at least begun, whilst the spore-cell remained organically united or in intimate apposition with the parent cells at each side.

Whether, as suggested by Prof. Dyer, the "hemispherical depositions of cellulose" sometimes met with on the inner side of the pollen-cell wall, *e.g.* in *Cucurbita pepo* (Sachs's 'Text Book,' p. 32, woodcut *v*), are to be considered analogous to the structure ("stoppers") here adverted to is probably questionable, but is doubtless deserving of further investigation.

are formed at all, or what special function they subserve, is not apparent; but the marvel is, that no sooner are they in existence than the openings seem to be thereupon again methodically plugged up.

The terminal pits, with their corresponding stoppers belonging to the same cell, are as far as possible distant from each other, at the remote basal and upper ends of the cavity, whilst the pits appertaining to neighbouring cells (as is usual where pits occur in higher plants) are placed directly opposite to one another. Each pit is somewhat narrower at its inner end than at the mouth; hence the two pits, viewed together, present an outline like that of a "pulley" in edge-view (Pl. XXVIII. figs. 11, 18). In the long and large cells of the main stems the pits are the largest, whilst they diminish gradually in size in the joints of the upper portions of the principal stems, or of the secondary or tertiary rachises, *pari passu* with their degree of tapering or attenuation (that is to say, with the decreasing size of the cells), until in the joints of the ultimate branches or pinnæ they become at last very minute, like mere granules or dots, but still quite perceptible (Pl. XXVIII. figs. 2 & 14).

So far as can be learned by a close examination in joints which have not become injured, the primary membranes of the joint-cells seem to close up the bottoms of these adjacent pits; at least, a line can readily enough be discerned occupying that position (figs. 11, 16, 18). But frequently this appears, on examination with a high power, to have become obliterated; not only so, but instances were noticeable where the contracted protoplasmic contents of one of the joints (now quite colourless from the action of the spirit) had become from some cause thrust through the foramen (thus proving that these are real openings, not mere markings or even alterations of density or otherwise), the mass of contents (thus one half in one cell, the other in the other) roughly forming a figure-of-8 shape, owing to the constriction caused by the narrowness of the aperture.

Corresponding to this gradual diminution in the size of the pits of the stems and secondary branches onwards to the ultimate pinnules, there is not only a gradual diminution in the size of the "stoppers," as mentioned, but also a gradual modification of their figure. In those appertaining to the cells of the principal stems they are of a figure approximating to two thirds of a sphere; in the upper joints and in the smaller cells of the secondary and their lateral rachises they are of a figure nearly hemispherical (or kettledrum-shaped); and by degrees, as the cells diminish in size down to the smallest, they assume a nearly plano-convex figure, until finally, in the very smallest cells, they appear like mere dots, or brightish rounded or discoid granules. In all, it may be said, there is a more or less evident slightly projecting *rim* around the flat side, which rim often presents a slightly crenulated appearance (Pl. XXVIII. fig. 12). In those of the smaller dimensions and of a plano-convex figure, however, the margin appears to be somewhat "bevelled off," and the crenulations forming an inner series. The convex or hemispherical surface is always quite smooth, and even glossy in appearance; in dried examples it may become more or less broken or altered. The substance appears of a colourless, semitransparent consistence. It is the plane side which is apposed to the opening of the pits, than which it is a good deal larger, closing it up like a lid—the

convex surface being towards the cavity of the cell. Strictly speaking, that portion of the superficies had better be called truncate rather than plane, as, especially in the larger examples of these bodies, it can readily be seen to be hollowed out or excavated in a rather irregular manner (Pl. XXVIII. figs. 11, 16, 18). Sometimes this hollowing out is a mere simple concavity; or this may show at its middle a secondary depression, or even a tertiary somewhere about the middle of the secondary, with sometimes a narrow inlet, then roundly expanding within. Thus the more or less irregular excavation may sometimes reach to a depth of a half to three quarters of the thickness of the whole body, but more frequently to only a quarter to a third the depth. Sometimes the excavation is nearly vertical laterally, and its bottom flat, in place of forming a concave depression, whilst that of an interior median secondary depression may be rounded or flat; and sometimes (though rarely) a narrow perforation may even pass right through to the hemispherical surface. In the larger examples especially, the inner surface of these inwardly variously shaped, though usually at their periphery pretty nearly circularly bounded excavations is seen to be not smooth but rough, even rugged, and of a somewhat granulated aspect.

When the two knob-like covers or stoppers are undisturbed *in situ*—that is to say, placed directly opposite to one another, each upon the opening of its own pit, and thus closing it up—and when the two together are viewed in conjunction with the outline of the two pits forming, as it were, a canal slightly narrowing halfway from one knob to the other, the whole offers a very curious and singular resemblance to a "rivet," as it were binding together the neighbouring joints; for the canal of the double pit is sufficiently deceptively like the shank of the quasi-rivet, the variously figured stoppers (as described) passing for its "heads," which clamp the structure on both sides. But when, as often happens, the stoppers become dislocated (see woodcut, p. 230), the quasi-stalk (that is the double pit) of course remains, dispelling an illusion of which the observer might at first glance be pardonably enough the victim.

These stoppers did not offer any evident reaction in presence of the usual tests for starch and cellulose; they disappeared totally on the specimen being boiled in caustic potash.

They are, so to speak, external to the so-called "primordial utricle," yet in intimate contact or union therewith. One could occasionally see the cell-contents still closely adherent to the convex surface of a stopper, partially contracted, and stretched into a conical shape, more and more expanding in width away from the stopper. Oftentimes the tension so induced caused the dislocation and pulling away of the stopper still coherent with the mass of plasma; or it might be "let go" halfway; at other times, and indeed more frequently, the cell-contents contracted, leaving the stopper *in situ*. In otherwise seemingly empty cells the stoppers, if not in their places (see woodcut), as is very frequently the case, could be found lying about in any part of the cavity and in any position. By their comparative dimensions one might safely enough predicate the particular pits to which they doubtless had belonged, and whence they had become dislocated (Pl. XXVIII. fig. 3).

But on examining the organization of this pretty alga, and in trying to gain a know-

ledge of the remarkable structure of which I have been endeavouring to convey an idea, one soon encounters an appearance, at first a very puzzling one, which, especially when viewed under a low power of the microscope, is readily misleading. Prof. Wright was the first to suggest the true solution of the contradictory appearance alluded to. But before I try to describe this, it will be necessary to convey an idea of the external or lateral form of the joints of the stems and rachises.

The cells of the "*stems*" and of each *principal* and *secondary rachis* of Mr. Moseley's plant are about $\frac{1}{2}$ to $\frac{1}{3}$ as broad as long, and of a figure which has somewhat the aspect of an elongate oval (Pl. XXVIII. fig. 3). When more closely studied, especially under a higher power, they are seen to be of a cylindrical form for about $\frac{3}{5}$ or $\frac{2}{3}$ their length from the base, at which point they become narrowed upwards, but in such a manner that thence to the summit the outline on each side gradually assumes a somewhat sigmoid curve, the inward flexure at the upper portion being greater and somewhat more arched than that at the lower. In other words, at the place where the nearly cylindrical lower portion of the cell ceases it becomes gradually contracted; the outline, however, does not form any angle, but is rounded off and is thence continuously curved inwards, then upwards for a time almost vertically, soon imperceptibly beginning to be uninterruptedly, but more rapidly, curved inwards on each side to the summit. The diameter of the cells at the summit is usually about $\frac{2}{5}$, or sometimes less, or it may be, on the other hand, nearly $\frac{1}{2}$ of that of the cylindrical portion. I have called the lower portion of the cells nearly cylindrical; but they are not absolutely so, as they generally seem to be very gently and gradually concave on the lateral margins, the concavity being deepest about halfway from the base to the point where they become narrowed upwards. On the whole they mostly appear to be very slightly dilated from the concave middle to that point; that is to say, the widest part of the joint, by some very slight degree, is that just before where they begin to be narrowed by the sides curving inwards. So much for the contour (be it always understood of the cells of the principal stems and rachises) presented in the ordinary view, so far as relates to their external (that is lateral) boundary.

I say, the ordinary view presented; for the habit of this plant being repeatedly distichous, the principal stems, branches, rachises, and their pinnæ or ultimate terminal offshoots, all lie in pretty nearly a common plane; hence a portion detached, however small, almost necessarily comes to be viewed from one or other of its plane aspects. The description given above of the lateral contour applies, it will be of course understood, to the joints so viewed.

Now when they are examined in that position, the lower end of each joint of the principal stems and rachises seems to be of a more or less conical figure, and broadly and bluntly rounded at the extremity, and as if projecting downwards into the joint immediately below; the upper portion of the latter necessarily introverted to receive it (Pl. XXVIII. figs. 3, 10, 11, 14, 16; Pl. XXIX. figs. 15, 18). Not only has the structure the appearance described, but (if we are viewing this alga under a higher power) a slight alteration of focus further shows the base of the joints as broadly rounded off at a higher level, and as if the apex of the joint in [illegible]ely below it were in close apposition

thereto. If the plant be viewed under a low power, the two contours—the broadly rounded and the deep conical—come into view nearly simultaneously, and we have the curious and contradictory appearance of the joints having, as it were, *two bottoms*; and this is what gives rise to the puzzling appearance alluded to. Now the *pits*, with their accompanying remarkable *knob-like stoppers, are seen to occur in the nearly transverse septum over the seeming conical base.* If there were a conical base of the upper joint, passing down into and introverting the tip of the joint immediately below, how could the knob or stopper of the upper end of the lower joint get past the barrier, and become opposed, on its own pit, to that at the bottom of the upper joint? Without any opening or passage, manifestly it could not be so deposited in its proper place.

The curious appearance of the introversion of the upper end of the lower joint might, indeed, possibly meet its explanation by assuming an interspace, from this ordinary aspect of a bluntly triangular or conical figure, between the two joints; somewhat comparable to the very differently shaped interspace between the mutually introverted ends of several forms of *Spirogyra*, but in the present plant, indeed, only one (the lower) joint being introverted. But even if this were true, it would not explain the pair of directly opposed "knobs;" for one would be at the base of the upper joint, and the other must then be in an "intercellular space," and therefore outside the cavity of the lower joint, thus offering really no explanation, and in truth presenting a puzzle just as difficult of solution as ever.

The fact is that the apparent introversion of the upper end of the lower joint by the lower end of the upper joint projecting downwards into it, an interpretation which naturally occurs to every one on first looking at this plant, is illusory.

So illusory is it, indeed, that Harvey himself, in describing his *Ballia Brunonia*, directly falls into the error, and quite misapprehends the true state of affairs *. He actually describes the structure, speaking of the joints of the rachis, thus:—"Articulus singulus apice concavus, basi convexus, superior in inferiorem insertus, e cellula unica formatus, sacculam *endochromæ* includens;" and afterwards he says, "each joint is concave at its superior end, convex at its inferior, having thus a somewhat cordate figure, the convex end being inserted into the joint immediately below it, while the concave receives in like manner the one above. These joints consist of a single cellule, and contain a bag of colouring matter which is collapsed in a dry state." As will be seen, the true structure is quite the reverse of Harvey's description; whilst he is altogether silent as regards the pits and stoppers, whatever be their value or significance. Nor does it appear that subsequent authors had detected the fallacy or noticed these curious "stoppers."

The true explanation is, that the lower end of each joint is in fact deeply cleft or forked laterally—that is, forming two wedge-shaped subdivisions; and these latter are tapered off towards each front, more or less conically, and then truncato-rotund, or rounded off subhemispherically. To some extent it might not be altogether inaptly compared to the top of a bishop's mitre.

* Harvey, "Description of *Ballia*, a new genus of Algæ," in Hooker's Journal of Botany, 1840, p. 190.

Now, having before described the mode of narrowing upwards of the upper ends of the joints and their lateral contour (in " ordinary " view), it remains to say further that they are from both front aspects narrowed upwards—so as to offer a blunt wedge-shape, rounded at tip, if they were viewed laterally—and so as to fit into the deep similarly figured notch of the lower end of the joint immediately above. The boundary at the summit is somewhat concave, adapted to the convex base of the interior of the notch of the joint above; but as it is considerably narrower, its concavity does not so readily strike the eye, and it might be regarded as straight or nearly so. Thus each joint might be said to be, as it were, equitant upon or to sit astride the wedge-shaped top of the joint immediately below; its more or less tapering or narrower subdivisions (one of which is seen in either ordinary " front view " of the frond) giving rise to the at first pardonable enough error, that there is a projection into and introversion of the cell immediately below.

Thus the true state of affairs is just the reverse of what one naturally is first inclined to imagine; it is the base (not the summit) of each joint which is introverted to make room for the tapering upper end of the joint immediately below it. But this introversion takes place in the peculiar manner and gives rise to the configuration described—this, as it were, " splicing together " of the joints doubtless adding to the tenacity of this rigid alga. That this is the true explanation I have satisfied myself by breaking up a small portion of the plant, and as much as possible denuding little fragments of their branches; and I thereby succeeded in getting a lateral view of a filament, otherwise necessarily, as has been mentioned, extremely difficult to obtain. In this view the marginal contour of a filament is pretty nearly straight from end to end (Pl. XXVIII. fig. 9).

From the description already given it will be observed that—owing to the narrowing upwards with a curved outline of the upper ends of the joints of the principal stems and secondary rachises, and to the peculiar figure presented by the basal end of the joint above it, coming down to meet it with the curve appertaining to the inner angle of the great " notch " therein—opposite each " splice " there exists what may be called a recurring narrowing of the filament (Pl. XXVIII. figs. 3, 14; Pl. XXIX. figs. 13, 17).

Owing to the peculiar contours of the joints being ignored in the figures extant, as a matter of course these shallow sinuses are not represented; the lateral margins are shown rather as those of broadly truncato-ovate cells. Still less is there any indication that, as is the case, each of these shallow sinuses is filled by a cell (Pl. XXVIII. figs. 3, 10, 11, 14; Pl. XXIX. figs. 17, 18). When fully formed, this intervening cell appears to be either quinquangular or sexangular, but in different parts of the plant of very varying proportional figure. And it is from this cell—never directly from the rachis-joint itself—that the lateral branches take origin.

These lateral cells, which I would denominate " ramification-cells " are either pentagonal or hexagonal; and the five or six sides (as the case may be) are of very unequal lengths. Two of the sides are apposed to the joints of the rachis; two beyond these are external and always unchanged; and the one or two remaining sides intervene between it and a ramification. The longest side in the pentagonal cells is that in apposition with the whole of the curved (that is, attenuated) upper portion of the joint of the

rachis. The next longest is that opposite thereto, external, and forming with the first an extremely acute angle (2); the third longest is that forming an obtuse angle with this latter; and on it (3), as will be explained, stands the first joint of a branch; the fourth in length is that in apposition to the curved interior of the great notch in the lower part of the joint (4); and the shortest (which is very short) is that joining the last with the second longest (or that side bearing the branch) (5). When there are six sides the relative length of the sides is the same, and the additional side (6) is nearly equal in length to, and immediately under, that bearing the primary branch, and is itself (as will be explained) surmounted by a minor shorter (stipule-like) branch.

Now the mode of origin of these ramification-cells is seen to be by the formation of a peculiarly *curved septum* at one or (mostly) both sides of the joint of the rachis, previously cylindrical, or nearly so, all the way from its base to its summit—this septum beginning at its lower extremity from the point, about three fifths or two thirds from the base of the rachis-cell (before described), and ending at its upper extremity a little within the base of the joint immediately above (Pl. XXVIII. fig. 5). This septum (1) takes a sigmoid curve as viewed from above, and is at the same time hollow or concave towards the ramification-cell, convex towards the rachis-cell, imparting the peculiar shape to the latter, as previously described. The cell thus cut off from the rachis-cell, as will be seen (it will of course be understood, when viewed from the "front"), at first forms a scalene triangle—one side only, however (the outer), being quite straight, its lower end very attenuated, and its angle there very acute.

In the formation of this septum we again encounter the curious character of an opposite pair of pits with their stoppers, every pit having its corresponding opposite fellow, the likeness of a "rivet" being still carried out (omitted in the diagrammatic figure 5). The pair of pits in the new septum is placed about one third of the way upwards from the acutely angular bottom of the ramification-cell (*a*, fig. 10). Just as this cell is much smaller than the joint of the rachis, so the pits, with their stoppers, are much smaller than those at each end of the latter. If ramification-cells are formed (as mostly, or indeed nearly always happens) at each side of the joint of the rachis (when formed at all), then the latter has two opposite lateral pits in its wall, in addition to the terminal; if only one ramification-cell be formed, then, of course, it has only one lateral pit. At this point, of course, the ramification-cell itself has but one pit—that is, the one opposite to and forming the fellow of the lateral pit of the rachis-joint.

The ramification-cell now soon grows out laterally in an inflated manner towards the upper end, the convex outgrowth being directed obliquely upwards (figs. 5 and 10). If viewed inverted, its noselike upper portion thus produced is now cut off by a curved concave septum, the concave surface being upwards—that is, the convex surface towards the cavity of the ramification-cell. The interposition of this septum makes the ramification-cell now five-sided—one of the sides (as before mentioned) being bounded by the septum just formed, the two adjoining sides, between which it intervenes, being the outer exposed portions of the ramification-cell now pushed out laterally, the upper one remaining very short and never further altered; whilst the two remaining sides are, of course, those (as before mentioned) in apposition with the lower portion of the upper joint of the

rachis, the other in apposition with the longer portion of the lower joint of the rachis respectively.

The upper (subhemispherical) portion of the ramification-cell, thus cut off by the curved, hollowed, oblique septum, is the *first joint* of a simple branch or (it may be eventually) of a subsidiary rachis (Pl. XXVIII. figs. 10 & 11). Before taking leave of this cell for the present, it is only necessary to say that at the middle of the septum is formed a pit—a double pit, it will be, of course, understood, each with its stopper. At this point, then, the five-sided ramification-cell has now, of course, two pits—one, as explained, opposite the corresponding pit of the rachis-cell, the other (younger) corresponding to the pit of the basal cell of the branch; and as the former pair of pits, with their stoppers, are smaller than those at the ends of the rachis-cell, so the latter, in their turn, are smaller still than the former.

A ramification-cell having reached this point may seemingly remain permanently so (in Mr. Moseley's plant many, by far the majority, do so); but certain of them proceed further.

If then they proceed to further development, the next stage is that from a point from about a third to scarcely half way from the outer side of the septum, cutting off the first branch-joint from the ramification-cell, a fresh curved and hollowed septum is produced; this extends thence to about the middle of the lower and outer free and exposed (external) side of the ramification-cell, its concave side outward—that is, its convex side (as before) towards the cavity of the ramification-cell (6, in figs. 10 & 11). This latter has now reached the six-sided form above mentioned. Obviously the portion cut off therefrom is at first triangular, with only one exposed or external side—this being, in fact, the upper portion of the lower free and external side of the primary ramification-cell, which lower portion whereof still forms one of its boundaries, and of course still free and external. Again, we have to note the formation in this second septum of the opposite pairs of pits and their stoppers, occupying a position about one third of the distance from the lower end of the septum. The primary ramification-cell at this point, it will be seen, has now three pits—the third and last formed being that in the freshly formed septum, and placed at a point about a third of the distance from its lower end, and opposite to which it has its fellow pit and stopper.

The triangular portion so cut off (which has one pit, with its stopper, in the septum between it and the other ramification-cell, being that first mentioned), like its predecessor, grows out at first laterally, and then obliquely upwards in a roundly inflated manner, this projecting portion being soon cut off by a fresh septum in such a way that the lower remains as a five-sided cell. This latter may, in fact, be denominated a ramification-cell of the second degree ($r\ c^2$, figs. 10 & 11); and the upper portion cut off therefrom forms the basal or primary joint of a secondary or accessory branch—the septum so cutting it off bearing again its medium pair of pits and stoppers, still smaller in size.

The five sides of the ramification-cell of the second degree, when the basal cell of the accessory branch is cut off, are thus made up:—1st. The upper portion of what was once the outer free side of the ramification-cell of the first degree, now pushed out laterally and obliquely (1″); 2nd. The septum cutting it off therefrom (2″); 3rd. The

portion of the septum cutting off the first joint of the upper branch from the ramification-cell of the first degree (3″); 4th. The (whole of the) septum cutting off the first joint of the lower branch from the ramification-cell of the second degree itself (4″); and, 5th, a very short side joining the two latter together, produced by the turning aside of the outgrowing extension of the ramification-cell of the second degree in its less advanced stage (5″).

Leaving this lower minor or secondary branch (as in the case of the older and upper one) for the present, we come to a point whence it is far more difficult to follow out the structure.

On taking up the description of *Ballia callitricha* (Ag.), Harvey, as given by Agardh under the name *Sphacelaria callitricha*, the plant he had in view is thus, in part, described: "*Caule filis confervoideis vestito*" * . . . . So also Prof. Harvey refers to the external "plexus of filaments."

On looking at a piece of our plant, these "fila confervoidea," or filaments, are indeed a prominent, but a very confusing feature, clothing, as they do, with a dense and intricately matted and tangled jungle the whole of the principal stems and some of the secondary rachises, the free ends of the filaments sticking about in every direction. This clothing might call to mind a tree densely covered with ivy, or, perhaps more fitly, might suggest a moss coated with *Chroolepus aureum*, only that the latter plant, when investing the moss, makes a smooth pile.

The authors referred to seem not to have investigated the relations of this plexus of "confervoid filaments" to the more handsome distichously branched *Ballia*-plant. I therefore desired the more to try to "make head or tail" of the confusing object before me, so far as regards the accessory clothing of what might be regarded as the *Ballia* proper (Pl. XXVIII. figs. 1, 4, 15; Pl. XXIX. fig. 14).

Not to speak of the general appearance and the similar thick-walled character of the cells of these filaments, two characters would set aside any possible supposition that these were not really part and parcel of the make-up of the *Ballia*. One of these was the presence in every one of the here directly transverse septa, separating their comparatively short quadrate joints, of a minute pair of pits with their stoppers (Pl. XXVIII. figs. 6, 7); the other, that when they branched it was seemingly by the interposition of a ramification-cell, but not of the same figure as those of the distichous stems and branches as described (figs. 6, 7).

Looking more closely into the build-up of this clothing of the stems and some of the rachises of the plants, it is readily enough seen that this is most dense at the lower portions, less and less so towards the upper portion of the plant, until it at last is wanting. It is also readily enough seen, by focusing "through and through," that at the lower portions the main stems are covered all round by a single layer of thick-walled elongate cells, mutually closely apposed, of various irregularly curved and crooked figure, or even somewhat rugged within—and that these cells are separated by *oblique* septa, these *latter* furnished with their median minute pairs of pits and stoppers, sometimes an extremity of some of the cells growing on so as somewhat to overlap the adjoining

* 'Icones Algarum,' no. vi. (t. 6).

one, their apices rounded. Thus this cortical stratum of cells somewhat resembles a kind of pleurenchymatous or prosenchymatous tissue. As our examination is carried from below upwards, this cortical stratum becomes more confined to the margins, leaving more or less of the stem-joints bare at the middle, until by-and-by it disappears altogether.

Here and there, with patience, one can probably meet with a profile view of the point whence the cells of this pleurenchymatoid cortical stratum is given off from one of the multitudinous branches which stick about most confusedly in all directions. In Mr. Moseley's plant these seem scarcely ever themselves to become branched, but form only indefinitely long "confervoid" filaments. Whilst, as mentioned, the septa of the vertical cortical cells are oblique, those of the branches given off therefrom are ever transverse; but, like those of the former, every septum here, again, has its minute pair of pits and stoppers. Only occasionally one can get a satisfactory profile view of the place of ramification; and it can be seen that this process here too is sometimes brought about by the intervention of a "ramification-cell." But this does not maintain the same figure as that of a rachis-cell as above described. Here, however, as there, an oblique, sometimes curved, septum is formed just under one of the ordinary oblique septa of a cortical cell, reaching from a point, say, about a quarter of the length of the septum from the outer wall to a short distance down the lateral margin of the cortical cell. Thus a minor cell is cut off, forming in this view a scalene triangle, two of its angles being acute, one obtuse. Soon the upper portion of its free side (being in fact a portion of the original outer margin of the cortical cell itself) grows out laterally, and, by apical growth and repeated subdivision of its apical cell, gives rise to one of the long accessory filaments, every septum, as mentioned, having its pair of minute pits and stoppers. The cells gradually diminish in size; in other words, the filaments gradually taper. The apical cell, when full-grown, is conical, its apex acuminate; but until then the apical cell is bluntly rounded. Whether, on the occasion of the giving-off of these lateral branches a ramification-cell is always formed, or whether they sometimes branch off without that preliminary by a simple outgrowth, merely standing off, as they sometimes seem to do, like a thumb to a glove, I could not decide.

So much for the ramifications of the cortical cells and the mode in which they themselves coat the principal rachises. Within one of these, so coated, one can see, by focusing down, shimmering through the investing cortical layer, the great pits and stoppers of the largest size, as well as the contours of the joints, with their ramification-cells giving off subsidiary rachises. These latter project through the cortical stratum of cells; and by far the greater number of these subsidiary branches themselves are naked. At a first glance, the question might propound itself, why do the investing fibres "run up" only a few of the subsidiary branches, and not all? why are they so much more dense low down, as compared with the upper portions of the stems and such rachises as they do invest?

This leads to the inquiry, What is the origin of the cortical cells (we have seen the origin from them of their lateral branches), and what their relation to what may, as before, be called the "*Ballia* proper"? And this is just an inquiry to which it is very

hard to obtain a reply; nor do I think that, without the opportunity to examine a *Ballia*-specimen kindly sent me by Professor Thiselton Dyer (also from Kerguelen's Land, collected by the Rev. A. E. Eaton) (Pl. XXVIII. figs. 13–18), I should have been able to satisfy myself on this point from the specimen in Mr. Moseley's collection, owing to the extremely crowded and nearly impenetrably dense investing envelope.

To try to follow out, then, the relation of the cortical cells to the rachises they invest, we must now revert to the ramification-cells of the second degree before described.

These we left as so many five-sided cells—that is to say, after the formation of the septum cutting off therefrom the portion destined to become the first joint of the lower minor accessory branch. In certain of these yet another curved septum makes its appearance: this, as might be expected, from the later period of its formation, is, by comparison, thin; and I have not been able to see in it the usual pit (or pair of pits); but I would not say that they may not be there (Pl. XXVIII. fig. 11, *x*). This septum reaches from a point about one third of the distance from below upwards of the septum cutting off the first cell of the accessory branch, to very near the lower angle of the cell (ramification-cell of the second degree). It is much curved, and has its convex side upwards or towards the cavity of the cell, and its concave side towards the portion cut off. The upper portion is, as will be seen, still five-sided, the new side (made by the new septum) being considerably arched. This portion seems never again to divide or grow in any way, thus as if of no further moment ($r\ c^2$, fig. 18). The lower portion cut off therefrom is at first subtriangular or subquadrangular, one side exposed—that is, external (being the lower outer one of the original ramification-cell of the second degree, as previously described); the other a portion (scarcely one third) of the septum, cutting off the first joint of the accessory branch; and another the new curved septum—which latter, if it gradually passes as far as the lower angle, causes the new cell to be trilateral; if, however, it terminates (ere it reaches that) somewhere near the angle, and against the adjacent side of the ramification-cell of the first degree, then we have a cell of quadrilateral outline. This last cell then, as will be seen, when it is produced, might possibly correctly be called a ramification-cell of the *third* degree ($r\ c^3$, fig. 18).

The next stage seems now to be, that the outer lower margin of this ramification-cell of the "third degree" becomes, as it were, somewhat abruptly pushed or bulged out downwards at about its middle point—this bulge soon, however, taking a more outward and lateral direction, the thick membrane becoming somewhat doubled upon itself. Sometimes one might fancifully suppose that this doubling outwards laterally got some assistance by a mechanical "dint" from without (*x*, fig. 17), imparted a little to one side of the nearly similar bulge from within; for the outline now shows this twice bent appearance. This doubling upon itself, backwards and outwards, becomes more pronounced; the lower portion becomes enlarged and inflated; and soon there is presented a large ovate external addition to this ramification-cell of the third degree (*cort. cell* 1, figs. 17, 18). This accession, in length downwards (alongside of the rachis-cell below), is about equal to that of the older portion above when first formed, and in width twice as great as that of the original portion; at the same time this additional ovate external

portion is now itself about twice as long downwards as broad. This point attained, now another septum is formed, of peculiar curvature, and stretching into the cavity of the large ovate new extension thereto, and thus, whilst it cuts off the larger portion, still leaves the ramification-cell of the third degree larger than it was originally—in fact, nearly twice the size. Having progressed so far in the examination, the structure becomes more and more difficult to follow. However, the septum last mentioned seems to take a curve from a point opposite to the sudden outer doubling back of the wall, and with a considerable sweep (something like the curved hook of a "note of interrogation") then passes quickly round to a point pretty nearly opposite the lower angle of the ramification-cell of the first degree. Thus the ramification-cell of the third degree, viewed in connexion with the portion added to it, has acquired a somewhat sigmoid curvature, the extremities broadly rounded; or it presents the figure of a subcylindrical cell with bluntly rounded apices, somewhat suddenly twice bent near the middle. Now, in the *lower portion cut off* (after forming this curved cell, and not belonging thereto) we have the first cell of a dependent appressed filament, thereafter elongating and repeatedly subdividing by oblique septa, and contributing to form the cortical stratum described. The cells go on so growing until they reach the node below, and there seem to divaricate. But the bent cell above seems to have more to do: it sends a protuberance out from each side (that is, towards each "front" of the flat frond of the *Ballia* plant), each of these forming a basal joint of further dependent cortical filaments, which, by passing downwards somewhat obliquely, cover more of the front of such main stems and principal rachises as proceed to this development (*cort. cell* 2, figs. 17, 18). At what point the very first septum is formed I could not make out exactly. Arguing from the analogy afforded by the mode of branching lower down, I suppose a septum is very early interposed upon the formation of a convex expansion, at both "fronts" (of the frond) of the lower portion of the bent cell—such septum cutting off that portion as the first joint of the cortical filament, which is dependent at each side of that previously described, these two having the latter between them, one running down on one front of the frond, the other on the other aspect.

It seems, however, sometimes to happen that no septum is formed in the ramification-cell of the second degree, and thus no portion thereof is cut off behind as useless; but the process described can go on, this omission notwithstanding. There is then no ramification-cell of the "third" degree formed. That of the second degree having had cut off from it the first cell of the lower accessory branch, proceeds to develop from its basal portion, by the outgrowing thereof and formation of the curved septum as described. The extreme lateral cortical filament, and at both front surfaces (of the frond), gives off the protuberances (keeping the former between them as described), which grow into further cortical filaments, directed more across the front aspects of the rachis as described.

The mode of branching of the dependent cortical cells is by repeated dichotomy. Close to the rounded apex of the terminal cell two septa are formed (making a V); these of course cut off two chords or cells of at first plano-convex figure, which, expanding and elongating downwards, grow side by side as the first joints of two collateral branches. As the filaments grow downwards, occasionally thus branching, they cover first the margins, then more and more of the frontal surfaces of the stem; and they keep closely

apposed to one another and to the cells of the stem or rachis, leaving (especially lower down) very few "intercellular spaces" (that is, intermediate bare places of the stem). When these occur they are of irregularly acutely lanceolate outline. The largest intercellular spaces are those, of course, through which the lateral branches or subsidiary rachises project—left necessarily by this descendent investing cortical stratum of cells as they pass downwards to each recurrent node or joint of the great stem or rachis, and from each of which in the same way new ones are given off in their turn.

If a lateral rachis possesses such a cortical stratum of cells, they belong to and emanate from its own nodes; for such dependent cells on arriving at a branch never become directed upwards to cover it, but the system passes downwards by the same stem to the base. The cells forming this cortical stratum soon begin to give off their own branches (as described), and more and more copiously as they descend, until the great confused tangled "plexus" is produced.

In order to complete the description of Mr. Moseley's plant we must now briefly revert to the ramification. We left the basal joint of a principal branch just formed by the cutting-off of the same from the ramification-cell of the first degree; and, in the same way, we left the first joint of a minor or accessory branch just formed by the cutting-off of the same from the ramification-cell of the second degree; but not all, indeed comparatively only a few, of the ramification-cells proceed to this latter development. The greater number of the ramification-cells remain as of the "first degree"—that is, five-sided; and the cell cut off gives rise, by continuous apical elongation and repeated division, to a more or less long (sometimes very long), often very stout, filament. There is in such cases no septum producing a ramification-cell of the second degree formed; and therefore no basal or accessory branch originates (Pl. XXVIII. fig. 3, its upper part).

Each branch so emanating from a principal stem has (it need hardly be said) nearly always a similar one opposite thereto, arising, as described, from its own ramification-cell; and from every node for long distances such a pair of branches may be thus distichously given off. But it sometimes happens that a branch may be without an opposite corresponding one: the lateral margin of the side so deficient remains straight from bottom to top; no ramification-cell is cut off—no branch (parts of fig. 2).

And just in the same way in Mr. Moseley's plant these lateral branches (pinnæ) may be, and often are, quite simple for the whole of their length (that is, with linear sides), no ramification-cells being cut off, therefore no pinnules formed.

But the overlapping of the laterally subdivided bases of the cells towards both fronts of the frond is more or less carried out in the joints of the lateral branches. The base of the first cell of a branch arising as described, and of each succeeding one, is, like that of the rachis-cells, laterally notched, but comparatively not at all so deeply: thus, like them, each cell sits astride the upper portion of the cell below; that of the first cell so bestrides, of course, the adjacent side of the ramification-cell. The basal subdivisions of the cells of the branches which partially overlap the cells below, one on one front, the other on the other front of the frond, however, are not so prolonged and so conically tapered off downwards as are the cells of the principal stems or rachises, but are rounded off subsemicircularly, or with a merely convex outline. Still those nearer the base of

the branch or lateral rachis are more deeply overlapped (in the manner described) than are the upper cells. As one proceeds upwards the overlapping is seen to be less and less pronounced; that is, the curve downwards in front of the subdivision of the bases of the component cells of the branch becomes less and less arched; whilst near to or at the top they appear hardly at all to overlap.

The cells very gradually diminish in size upwards; in other words, the branches gradually taper. The increase in length of the branch is effected only by the growth and subdivision of the terminal cell, the next lower cell never subdividing again (unless, of course, it should produce ramification-cells). During the progress of the growth of the branch the terminal cell appears to be rounded at the top; but when the branch attains its full length, and apical growth is over, the terminal cell becomes drawn out, long and conical, its summit acuminate, and its membrane thickened.

I may add that the cell-membrane, especially of the principal stems or ramifications, appears to be irregularly and longitudinally distinctly, though faintly, striate.

With the exception of the "stipule-like" secondary branchlet (given off from the ramification-cell of the second degree), the pinnæ (in Mr. Moseley's plant), in comparison with other forms, very seldom ramify; that is, they give off pinnules only here and there very fitfully. However, this lower external branchlet, unlike an ordinary pinna or pinnule, as has been seen, is not an ultimate emanation from the same series of cells (or, in other words, from the same subsidiary ramification) as the pinnæ proper, but it is a collateral and ultimate emanation from a series of cells (forming a main stem or a ramification) of a generation back. This collateral or accessory ramification, then, is as much an independent branch as the older one above, although it might (in error) be taken for a pinna springing therefrom. But inasmuch as this accessory branch is but a subsequent emanation, primarily owing its origin to the ramification-cell of the second degree, which in turn was formed by the subdivision of the primary ramification-cell, it could not therefore exist without having been preceded in time by the (larger) branch immediately over it, at the outside base of which it stands.

The secondary or subsequent rachises in Mr. Moseley's plant, and their simple branches or pinnæ, are usually pretty stout, taper very slowly, and stand off from one another at an acute angle, here and there often in a very scattered and irregular manner, giving off solitary branchlets, or little groups of pinnules—it need not be said, each ever preceded by a ramification-cell. It will be seen, then, that we have a plant of a considerably long-drawn-out and fastigiate habit. Though the branches and pinnæ lie pretty much in a common plane throughout, still the plane may be more or less altered through the extent of the aggregate formed by a plant of, say, a few inches in length (Pl. XXVIII. fig. 2).

It would be a very difficult matter, perhaps hardly possible, to trace out correctly the different layers or laminæ of the very thick walls of the rachises up into their ramifications. It seems that an outer layer of possibly numerous thin laminæ, forming a portion (the upper) of the original wall of each joint of a stem or rachis, reaching from below upwards, becomes diverted laterally, and thus continued forms the *outer layer* of the lower exterior wall of the ramification-cell. But soon afterwards, owing to the

tension to which it has been subjected during the outgrowth of the latter and of the ramification seated on it, it becomes gradually "thinned off to nothing" and, excepting any little of it left higher up (the mere softened or macerated remains), totally disappears. Its seeming (and why I say "seeming" only, will appear below) total disappearance is hastened when a ramification-cell of the second degree is formed, owing to the more sudden lateral diversion and increased tension of this layer caused thereby. The inner stratum of the free side of the ramification-cell of the first degree is deposited simultaneously with, inasmuch as it is a continuation of, that septum, shutting off therefrom the ramification-cell of the second degree; and it is carried onwards round the interior of the ramification-cell of the first degree. The lower portions of this layer converge towards the acute base of the cell, and there, mutually apposed, seem to pass vertically downwards in a very compressed state; moreover as a single layer between the outer layer of the base of the stem- or rachis-joint (from which we started) and an internal layer, which passes round the interior of the rachis-joint and at its upward parts (on both sides usually), it cuts off therefrom the ramification-cells of the first degree. Now when a secondary branch has fully grown, if we carry our examination upwards along the exterior of the primary branch (secondary rachis) immediately over the former, we see an outer layer somewhat sharply marked off from the inner, and this likewise "thinned off to nothing" upwards. Now I believe this layer was once in continuation with that below the subsidiary "stipule-like" branch, and which latter, as we saw, is (and of course always was) in continuation with the lower external layer of the stem- or rachis-joint itself; that is to say, it had been in continuation therewith prior to its having been forced asunder by the continued stretching and tension caused by the growth in the first place of the ramification-cell of the second degree, and afterwards of the branchlet seated thereon. Further, this upper outer layer last alluded to must have itself once formed part and parcel of the upper part of the original wall of the stem- or rachis-joint, anterior to the formation of the septum cutting off therefrom a ramification-cell of even the first degree—from whose expansion laterally it got its first impetus outwards, far away as it has now been transported from the place where it was originally deposited. And this is why I spoke of its seeming disappearance. Suppose now that the basal joint of a branch goes on to produce a ramification-cell (and a branchlet), we find immediately over the same a piece of external layer "thinning off to nothing" as before; this latter, again, must have been, I presume, pushed up and out from the ramification-cell just below it, and previous to that have formed so much of the upper portion of the basal joint of the branch, and so on. Possibly it may be assumed that something similar occurs, were it traceable, in ordinary branching confervoids; but so common is a gelatinous softening of the outer layers in such, that any traces of the mutual superposition of laminæ get lost.

On comparing this plant with examples of *Ballia callitricha* from the University herbarium, kindly placed at my disposal for comparison by Dr. Perceval Wright, one is at once struck by the very great difference in habit between the two. Indeed the same observation holds good as regards the further forms or species *B. Hombroniana* and *B. Brunonia*, distinguished by some from, and by others combined with *B. callitricha*.

I leave the thoroughly distinct forms of *B. Robertiana* (Harvey) and *B. Mariana* (Harvey) out of view, not having investigated them with sufficient pains to be able to contrast them in their relative bearing to the points presented by Mr. Moseley's plant; but confining our attention to those forms combined under the designation *B. callitricha*, we see they are all of beautifully more or less well-developed plumose habit, very unlike Mr. Moseley's form. It would, however, be trenching on rather unsafe ground for me to venture to distinguish this plant as a new species.

In *B. callitricha* and the forms conjoined with it under that designation, the whole that has been said in relation to Mr. Moseley's form, as regards the pits and stoppers, the ramification-cells and mode of evolution of the branches and cortex, in a general way applies. The differences in the different forms lie in the various figures of the different constituent cells forming the build-up of the plants, until we come to the ultimate pinnæ with their pinnules. Unlike Mr. Moseley's plant, where these ultimate pinnules are rarely and only fitfully given off, in the *B. callitricha* forms they are methodically and pretty uniformly given off from the cells of the ultimate little rachis—*always by interposition of a ramification-cell* of the first degree only, and so as to produce a plume of ovoid or lanceolate or hastate outline, according to the "species."

It becomes worthy of remark that whatever the outline of these plumes, and consequent effect or habit of the plant in its entirety, the lowest outer component thereof, looking like a pinnule of the same nature and origin as the rest, is not really so, but is in fact the homologue of the lateral "stipule-like" secondary branch described in Mr. Moseley's plant:—there mostly, or at least often, solitary; here, along with the close array of pinnules, contributing to make up the "plume," and rendering itself quite conformable with the true pinnules. That is to say, it is a true secondary branch, being an emanation from the ramification-cell of the second degree belonging to the older rachis from which that bearing the pinnæ starts, as this latter is an emanation from the preceding ramification-cell of the first degree; and from the ultimate minor rachis standing thereon, in turn there emanate all the pinnules standing above this secondary branch, which is conformable with the pinnules, and forms part and parcel of the "plume."

It sometimes, indeed, happens that this lower branch grows inordinately in length, refusing to comport itself like the line of pinnules above it; I did not, however, ever notice a case in which it branched or gave off secondary pinnules or "pinnellæ." In Mr. Eaton's form, sent by Prof. Dyer, the inordinate growth of this accessory branch seemed more common.

The ultimate terminal or apical "plume" of each ultimate rachis in the typical *B. callitricha* must, however, be excepted; for its pinnæ are wholly made up of short stout tapering branchlets, each standing on a ramification-cell, all of the first degree, a continuation of the penultimate rachis being its rachis. In other words, these do not go on to become ultimate rachises themselves, do not produce ramification-cells, hence no "pinnellæ;" but together they form an apical "plume," of more or less lozenge-shaped general outline; and sometimes the upper cells remain inactive, produce no ramification-cells, and do not ramify. Sometimes, indeed, one or two of these apical pinnæ (branchlets) may make an attempt from a few of their cells to give off ultimate pinnellæ,

though these sometimes reach only the formation of a ramification-cell—as indeed the effort to produce pinnellæ at the apices of some of the plumes lower down may get no further than the same preliminary stage.

In the "typical" form the ramifications given off from the cortical stratum are much more prone themselves to branch than in Mr. Moseley's. Several branches (from three to ten) are given off, generally alternately, in quick succession, and radiate in a kind of fan-like manner; each possesses always a preceding ramification-cell (five-sided when the branch is formed), as in Mr. Moseley's plant. The pits and stoppers are present, but not so conspicuously evident.

The differences between the "typical" *B. callitricha* and *B. Hombroniana* are very graphically shown in Mr. Tuffen West's delicately rendered drawings. More distinct still than they are from each other, appears Mr. Moseley's plant from either.

At first glance, *Ballia scoparia*, Harvey, seems hardly to belong to the same genus. Distinct as is the habit, and divergent as is this plant in several details from the preceding forms, there is still a good deal in common; but possibly, after all, the same characteristics may yet be found to be more forcibly presented in other algæ. So far as regards the pits, they are not confined to *Ballia* in Rhodophyceæ; these, as "pores," have long ago been pointed out by Nägeli. It is the "stoppers" (so called) which I fancy to be new.

Now in *B. scoparia* the pits are generally pretty evident, the stoppers not readily seen, presenting themselves as only little thin discoid bodies (Pl. XXIX. figs. 3–9). It likewise possesses a plexus of threads on the principal stems, of which more below.

Like the former, this species branches by interposition of "ramification-cells;" but these and the mode of branching are quite dissimilar.

Its general habit is aptly enough indicated by Dr. Harvey's specific name:—long-drawn-out and fastigiate; the "branches" scarcely thinner than the "stems," most irregularly given off at no particular intervals, and only at one side, and branches fitfully again branching (Pl. XXIX. fig. 2). The branches stand off with a slight curve from the cell on which they originate, and then proceed upwards at an acute angle to the "stem." The ends of the joints appear to be slightly hollowed; and the adjacent upper and lower ends mutually somewhat overlap, the outer lower margins being convexly rounded (figs. 8, 9). The upper portions of the branches give off unilaterally a succession of a few (1–5–6) of short spine-like uncinate bluntly acuminate branchlets (fig. 3); and when these are formed, that branch which bears them grows upwards no more; that is, its terminal cell ceases to subdivide, and its apex becomes acuminate, like the lateral spine-like branchlets.

Now the formation of the ramification-cell is puzzling. When a young one is viewed edgeways, it seems to form a lenticular hollowing in the thick wall of the joint (fig. 6); but how that could so originate is very questionable. It may be formed by a deposition of membrane all round the joint, but so as to shut out a portion of the "contents," which assumes that figure. Viewed from the "front" (fig. 9), this as yet very thin cell is seen to be of broadly elliptic figure, showing a minute sharply marked pit and stopper exactly in the centre. More grown, and viewed edgeways, one of these cells appears

much inflated inwardly towards the cavity of the joint, the median pit at least readily enough made out (Pl. XXIX. fig. 5).

It seems sufficiently surprising the comparatively considerable number of cases in which no further development appears to ensue. Sometimes one can trace three or four of these ramification-cells in as many joints in immediate succession at various parts of a "tuft" of this alga, and frequently in other places scattered here and there a single one. Possibly the rate of growth may be but very slow; and many of those incipient ramification-cells apparent in a given example probably would have gone on, were the plant undisturbed in its native habitat, to the development at some later period of further ramifications.

This process seems to take place simply by the projection of the outer side of the ramification-cell in an inflated manner (fig. 5), gradually expanding in an upward direction. When about half the length of an ordinary joint is attained, a septum is formed, the apex grows onwards, then a fresh septum, and so on, until the definite length of the branch is attained; the upper joints finally give off the acuminate spine-like branches, and the apical cell becomes itself almost spine-like and acuminate.

From the peculiar figure, as described, of the ramification-cell the branch has somewhat the appearance as if it issued through a lateral cleft of the wall of the joint bearing it; and the original inner convex boundary of the ramification-cell, being wider than the portion issuing from the side of the joint in which it is seated, lends to the whole much of the appearance of being a kind of graft, as it were, let in at that side of the joint whence it emanates (fig. 8).

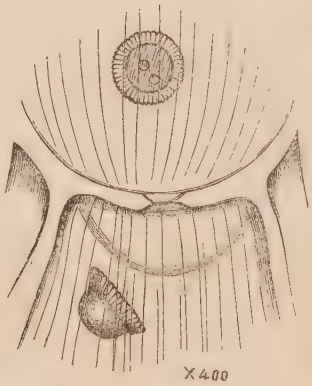
Notwithstanding that the mode of origin of the ramification-cells here seems to differ from that in the cortical cells of Mr. Moseley's plant, still, when the branching is effected, there is a sufficiently striking similarity in appearance in the "graft-like" aspect of the insertion of the ramification, and in the mode in which it stands off from the joint bearing it (Pl. XXVIII. fig. 7).

Towards the lower end of the plant decurrent branches are given off somewhat similar to those in the *callitricha* group; but here they do not seem to form a close "cortex." Their mode of origin seems to be very similar to that of the ordinary branches; but I was unable to alight on an example in as early a condition; primarily the ramification-cell seems to be similar.

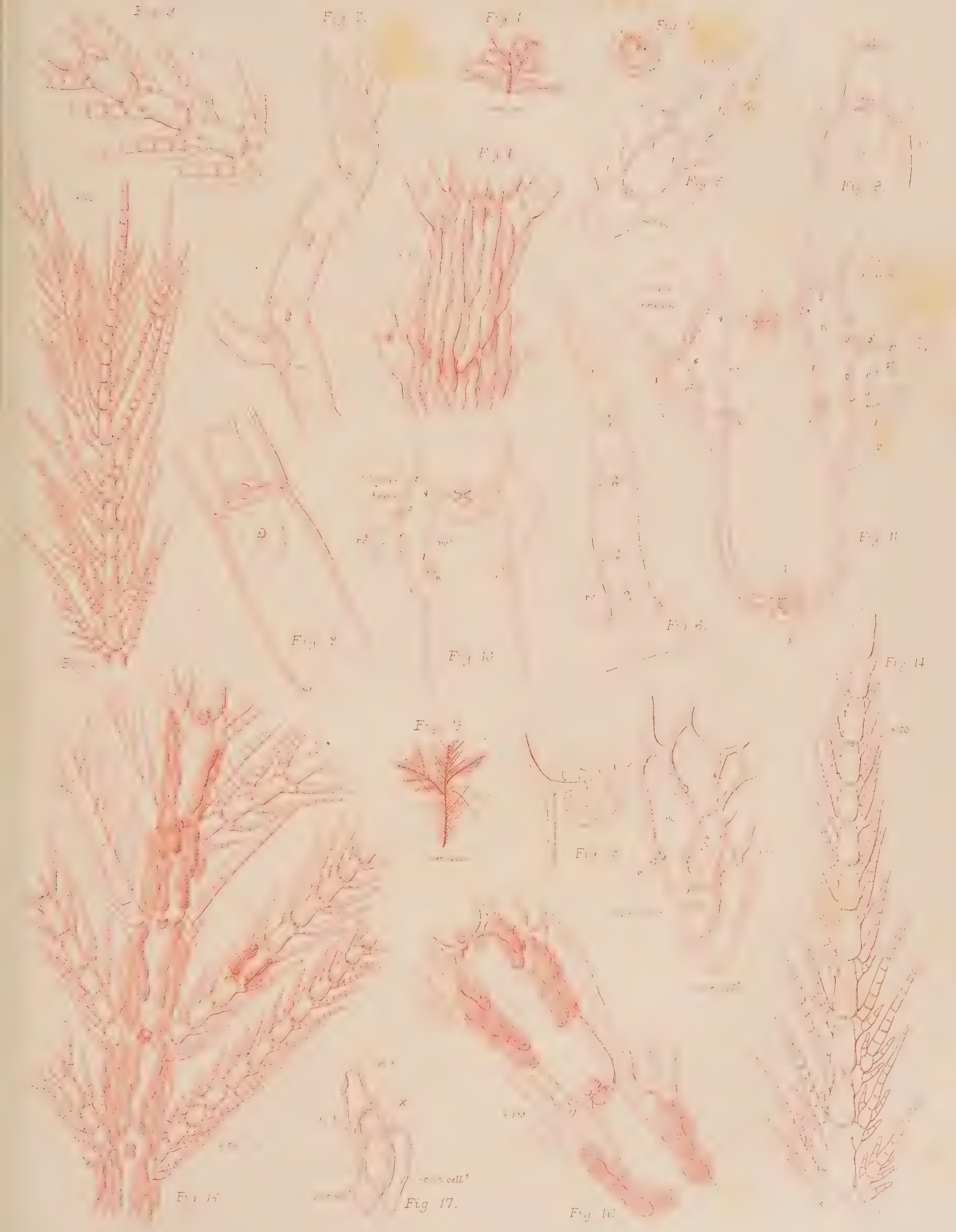
The ramification-cell here, however, when the decurrent branch is formed, does not seem to offer as much of the appearance of a "graft" let in at the side as does that of an ordinary branch (Pl. XXIX. figs. 10, 11). When it is fully formed it appears of a broadly ovate figure truncated below—that is, cut off there by the septum, dividing from it the next joint of the dependent branch; its inner lateral margin projects in a convex manner towards the cavity of the joint whence it emanates; and its outer boundary projects in a convex manner towards the surrounding medium. But this cell is always subdivided by a septum (x, in figs. 10, 11) into two unequal portions, the origin or significance of which I have been unable to make out. This septum runs in a curved manner, its convex side inwards, from about the upper apex (the whole plant being viewed vertically) of this truncato-ovate cell to near the outer lower angle (formed by the outer

bounding wall and the first transverse septum alluded to); it thus cuts off a portion (the outer and smaller) of doubly convex figure (? in figs. 10, 11) from the other portion (the inner and larger) of triangular figure, bounded, however, by two curved lines and one straight (*r c* in figs. 10, 11). The septum, concave towards the latter, and separating it from the original joint, possesses its minute pair of pits and stoppers; so does the flat septum separating off the first joint of the decurrent branch, as well as the subsequent septa; but there seems to be none in that septum, convex towards this triangular cell, which cuts off the lenticular portion alluded to. At what period this latter peculiar septum is formed, or for what purpose, as I have said, I could not make out; and it remains to me one of the puzzles connected with this plant. It seems, as it were, like a "ramification-cell" which never, however, goes on to produce a branch.

The apical cell, whose *punctum vegetationis* has impressed upon it the downward impetus, continues to grow onwards, repeatedly dividing by a transverse septum. It is not long ere this dependent branch begins itself to ramify; perhaps even the very first-formed joint may produce a ramification-cell quite like those of the ordinary erect branches; and, as in their case, often "ramification-cells" are present that do not seem to go any further. When ramifications are formed, which, indeed, is still very frequent, they stand off more approaching a right angle than do the ordinary branches (see Pl. XXIX. fig. 4); and they have the same "graft-like" appearance; the subsequent septa are transverse, and the pits often very obscure. Towards the base of the plant ultimately a dense irregular plexus of branching filaments is in this manner produced.



Drawing, in outline, of a joint of the stem from a portion of Mr. Moseley's example of *Ballia callitricha*. It shows the junction and coadaptation of the two cells, their partial invagination and the seeming double bottom, the double pit, and the pair of stoppers thrown out of position. One of the latter appears in profile; the other exhibits its truncate side or that surface which is apposed to the opening of the pit. Magnified about 400 diameters.



Tuffen West sc.

STRUCTURE & GROWTH OF BALIJA VALLISTRICHA

DESCRIPTION OF THE PLATES.

Plate XXVIII.

Illustrations of the minute structure and mode of growth of *Ballia callitricha.* Figs 1–12 are from the fragments of this alga, gathered by Mr. Moseley, of H.M.S. 'Challenger,' in Kerguelen's Land. Figs. 13–18 are from those obtained in the same island by the Rev. A. E. Eaton, during the Transit-of-Venus Expedition, and placed at the author's disposal by Mr. W. T. Thiselton Dyer.

Fig. 1. A portion of Mr. Moseley's plant: natural size.

Fig. 2. A portion of same, showing its habit and the fitful manner in which the ultimate branchlets are given off, and the paucity of any thing like the regular "plumes" of the other forms: × 20.

Fig. 3. A smaller portion, more highly magnified. The lower part of the figure shows the 6-*sided* ramification-cells, which therefore bear, besides the ordinary pinnæ (branches), the accessory minor branchlets. The upper part of the figure shows the 5-*sided* ramification-cells, which therefore are without the accessory branchlets. In some of the joints of the rachis the stoppers have become dislocated, and lie apart within the cavity. × 50.

Fig. 4. A node or joint of a rachis, showing the dependent cortical investment and the bases, with the intervening "ramification-cells," of four simple branches (*i. e.* without the accessory ones), the two lower being, of course, at the top of the next abutting joint beneath; the opposed pairs of stoppers can be seen above and below, the stopper at the top of the joint having become slightly displaced. × 100.

Fig. 5. Diagrammatic figure (founded, however, upon a young growing branch actually observed), showing the youngest and more advanced conditions of the ramification-cells. The letter *i* is placed against the septum in each case produced to cut off the triangular portion of the rachis-joint to become the ramification-cell. The letters *r c* indicate in all cases the "ramification-cell." The growing apical cell is still rounded; when fully formed it becomes acuminate.

Fig. 6. A branch given off from a cortical cell—that is to say, one of the component filaments of the great plexus standing off from a main stem or principal rachis: greatly magnified.

Fig. 7. Another filament giving off a branch in two places, also highly magnified: *r c*, ramification-cell.

Figs. 8, 9. Side views of a node of a rachis under a still higher power.

Fig. 10. Diagrammatic figure of the mode of growth of the ramification-cells, founded on cases actually observed in specimens: $r\,c^1$, ramification-cell of the "first" degree; $r\,c^2$, of the "second" degree. The figures 1–6 represent the different sides of the cell as adverted to in the text; *a a*, lateral pits and stoppers of the joint-cell; *b*, the terminal pits and stoppers.

Fig. 11. Similar but more advanced, showing now the base of the accessory branch (hence necessarily the ramification-cell of the second degree) fully formed. The figures 1″–3″ represent the different sides of this cell, as adverted to in the text (the figures 1–6 and the letters *a* and *b* as in preceding). These two figures indicate the manner in which the projections from the base of each of the joints overlap and sit astride upon the apices of the joints below, thus giving rise to the old error that they passed down into a pocket-like introversion of the same.

Fig. 12. A stopper of large size, seen from its flat surface.

Fig. 13. The Rev. A. E. Eaton's plant, of natural size.

Fig. 14. Same magnified, showing habit; near the top the branches simple, lower down showing

accessory branchlets (the ramification-cells with the change mentioned in text), lower down still the branches showing pinnæ. × 50.

Fig. 15. A portion of same plant more magnified. The branches have (all but one, which remains simple, having formed no ramification-cells) become secondary rachises; and the ramification-cells of the principal rachis have given off cortical cells: these have not yet completely clothed the rachis, in fact only on the sides; nor have they given off any lateral branches. In one place (fitfully enough) the ramification-cells on each side of a secondary rachis have given off cortical cells. The large pits and stoppers of the median rachis are very prominent; they are much smaller in the secondary rachises, gradually diminishing in size upwards, smaller still and gradually diminishing in the collateral branchlets and pinnæ, but, though reduced to mere dots, are always present. × 50.

Fig. 16. A small portion, similar to fig. 15, more magnified. × 100.

Fig. 17. Diagrammatic figure of the first cortical cells.

Fig. 18. Diagrammatic figure of the commencing growth of the cortical cells from the ramification of the "third" ($r\ c^3$); "cort. cell 1" indicates the first lateral cell, and "cort. cell 2" *one* of the *frontal* cells, which lay the foundation of the cortex, indicated in figs. 15 and 16.

Plate XXIX.

Fig. 1. Tuft of *Ballia scoparia,* of natural size.

Fig. 2. A portion of a plant, × 50.

Fig. 3. Diagrammatic figure of the extremity of a branch, showing two spine-like thickened acuminate branchlets, the apical cell also spine-like, thickened and acuminate; the pits and stoppers very minute and nearly obsolete.

Fig. 4. Mode of branching of cortical cells in this species.

Fig. 5. Commencement of a branch by the outgrowth of the lateral ramification-cell (*r c*).

Fig. 6. A stem or branch with a secondary branch, showing edge view of two ramification-cells (*rc, rc*).

Figs. 7, 8. The mode in which the branches appear as if inserted.

Fig. 9. A ramification-cell (*r c*), seen from the front, showing its elliptic figure (lenticular in edge view, see fig. 6) and central pit between it and the parent joint.

Figs. 10 and 11 show the mode of giving off of the dependent "cortical" cells from the principal stems: *r c,* the ramification-cells; *x,* the septum cutting off the lenticular cell (marked ?), of questionable purpose. In fig. 11, at *a* occurs one of the ultimately numerous branches going to make up the confused plexus seen in some specimens. They frequently show here and there the formation of the lenticular ramification-cells. It would have been better if fig. 11 had been inverted to indicate the dependent direction of these cortical ramifications.

Fig. 12. *Ballia callitricha* (typical): nat. size.

Fig. 13. A spray of this beautiful plant, × 50, showing its elegant closely set "plumes."

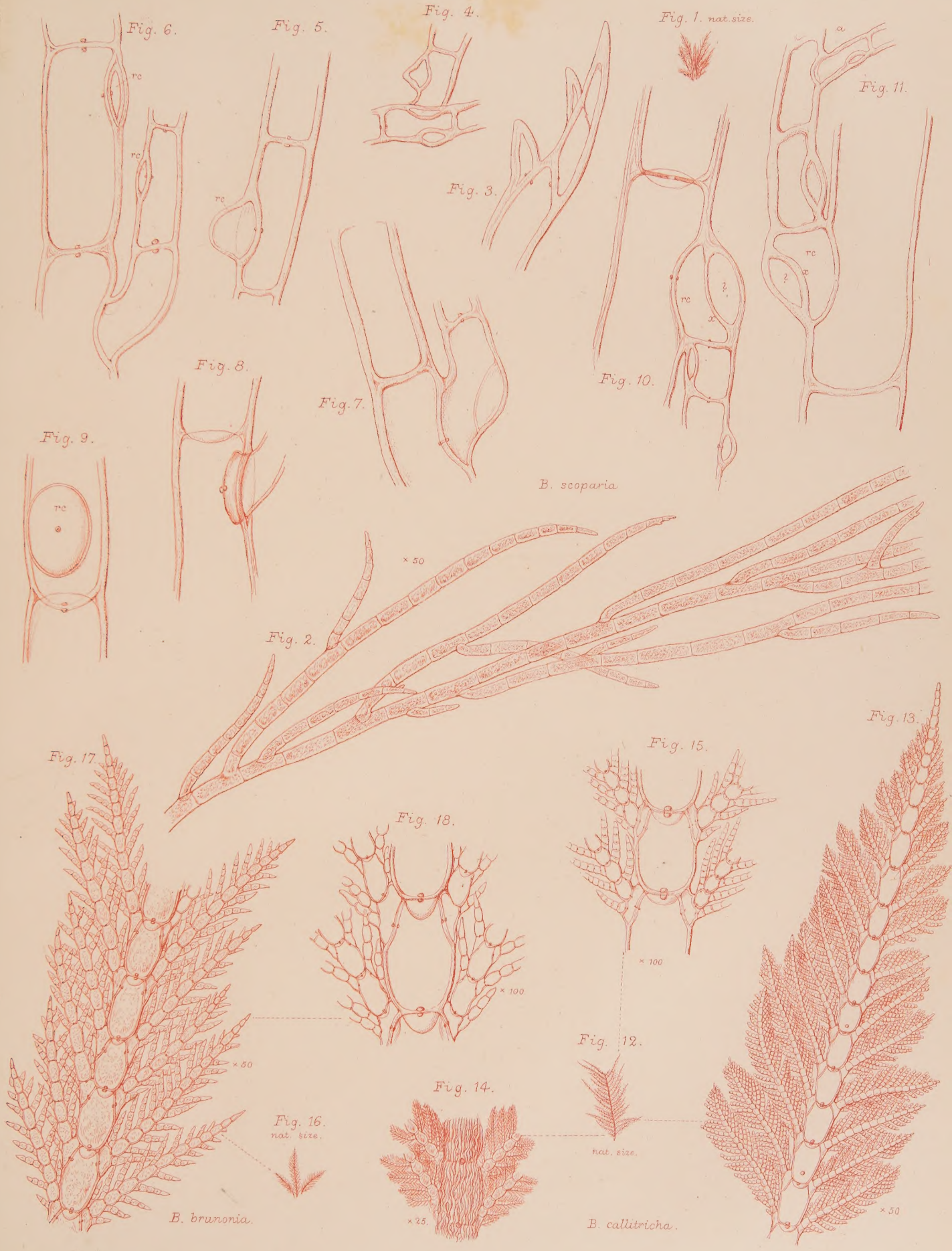
Fig. 14. Showing cortical investment: × 25.

Fig. 15. Same more highly magnified: × 100.

Fig. 16. Portion of *Ballia Brunonia,* of nat. size.

Fig. 17. Part of the same specimen, × 50. (Mr. Eaton's plant seems to accord more with this form.)

Fig. 18. Small portion, still more highly magnified: × 100.



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STRUCTURE & GROWTH, SPECIES OF BALLIA.

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